JUNOS™ Internet Software Configuration Guide

VPNs

Release 5.4

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About This Manual

This chapter provides a high-level overview of the *JUNOS Internet Software Configuration Guide: VPNs:*

Objectives

This manual provides an overview of the JUNOS Internet software virtual private network (VPN) functions, and describes how to configure VPNs on the router.

This manual documents Release 5.4 of the JUNOS Internet software. To obtain additional information about the JUNOS software—either corrections to information in this manual or information that might have been omitted from this manual—refer to the software release notes.

To obtain the most current version of this manual and the most current version of the software release notes, refer to the product documentation page on the Juniper Networks Web site, which is located at http://www.juniper.net/.

To order printed copies of this manual or to order a documentation CD-ROM, which contains this manual, please contact your sales representative.

Audience

This manual is designed for network administrators who are configuring a Juniper Networks router. It assumes that you have a broad understanding of networks in general, the Internet in particular, networking principles, and network configuration. This manual assumes that you are familiar with one or more of the following Internet routing protocols: Border Gateway Protocol (BGP), Routing Information Protocol (RIP), Intermediate System-to-Intermediate System (IS-IS), Open Shortest Path First (OSPF), Internet Control Message Protocol (ICMP) router discovery, Internet Group Management Protocol (IGMP), Distance Vector Multicast Routing Protocol (DVMRP), Protocol-Independent Multicast (PIM), Multiprotocol Label Switching (MPLS), Resource Reservation Protocol (RSVP), and Simple Network Management Protocol (SNMP).

Document Organization

This manual is divided into several parts. Each part describes a major functional area of the JUNOS software, and the individual chapters within a part describe the software commands of that functional area.

This manual contains the following parts and chapters:

- Preface, “About This Manual” (this chapter), provides a brief description of the contents and organization of this manual and describes how to contact customer support.
- Part 1, “VPN Overview,” provides an overview of Layer 2 and Layer 3 VPNs.
    - Chapter 1, “VPN Overview,” provides common VPN terminology and describes the major differences between Layer 2 and Layer 3 VPNs.
- Part 2, “Layer 2 VPNs,” describes how to configure the JUNOS software to support Layer 2 VPNs.
    - Chapter 2, “Layer 2 VPN Overview,” provides an overview of Layer 2 VPNs.
    - Chapter 3, “Layer 2 VPN Configuration Guidelines,” describes the minimum and optional configurations for Layer 2 VPNs.
    - Chapter 4, “Layer 2 VPN Configuration Example,” provides a configuration example for a Layer 2 VPN.
    - Chapter 5, “Summary of Layer 2 VPN Configuration Statements,” describes the statements used to configure Layer 2 VPNs.
- Part 3, “Layer 3 VPNs,” describes how to configure the JUNOS software to support Layer 3 VPNs.
    - Chapter 6, “Layer 3 VPN Overview,” provides an overview of Layer 3 VPNs.
    - Chapter 7, “Layer 3 VPN Configuration Guidelines,” describes the minimum and optional configurations for Layer 3 VPNs.
    - Chapter 8, “Layer 3 VPN Configuration Troubleshooting Guidelines,” provides guidance for troubleshooting Layer 3 VPNs.
    - Chapter 9, “Layer 3 VPN Configuration Examples,” provides configuration examples for Layer 3 VPNs.

    - Chapter 10, “Layer 3 VPN Internet Access Examples,” provides configuration examples that show how to configure Internet access for Layer 3 VPNs.

    - Chapter 11, “Summary of Layer 3 VPN Configuration Statements,” describes the statements used to configure Layer 3 VPNs.

- Part 4, “Interprovider and Carrier-of-Carriers VPNs,” describes how to configure the JUNOS software to support interprovider and carrier-of-carriers VPNs.

    - Chapter 12, “Interprovider and Carrier-of-Carriers VPNs Overview,” provides an overview of interprovider and carrier-of-carriers VPNs.

    - Chapter 13, “Interprovider and Carrier-of-Carriers Configuration Guidelines,” describes the minimum and optional configurations for interprovider and carrier-of-carriers VPNs.

    - Chapter 14, “Configuration Examples for Interprovider and Carrier-of-Carriers VPNs,” provides examples that show how to configure interprovider and carrier-of-carriers VPNs.

    - Chapter 15, “Summary of the Interprovider and Carrier-of-Carriers Configuration Statement,” describes the statement used to configure interprovider and carrier-of-carriers VPNs.

- Part 5, “Layer 2 Circuits,” describes how to configure Layer 2 circuits.

    - Chapter 16, “Layer 2 Virtual Circuits Configuration Guidelines,” describes how to configure Layer 2 virtual circuits.

    - Chapter 17, “Summary of Layer 2 Circuit Configuration Statements,” describes the statements used to configure Layer 2 circuits.

This manual also contains a glossary, a complete index, and an index of statements and commands.

Part Organization

The parts in this manual typically contain the following chapters:

- Overview—Provides background information about and discusses concepts related to the software component described in that part of the book.

- Configuration statements—Lists all the configuration statements available to configure the software component. This list is designed to provide an overview of the configuration statement hierarchy for that software component.

- Configuration guidelines—Describes how to configure all the features of the software component. The first section of the configuration guidelines describes the minimum configuration for that component, listing the configuration statements you must include to enable the software component on the router with only the bare minimum functionality. The remaining sections in the configuration guidelines are generally arranged so that the most common features are near the beginning.

- Statement summary—A reference that lists all configuration statements alphabetically and explains each statement and all its options. The explanation of each configuration statement consists of the following parts:
  - Syntax—Describes the full syntax of the configuration statement. For an explanation of how to read the syntax statements, see "Documentation Conventions" on page xxi.
  - Hierarchy level—Tells where in the configuration statement hierarchy you include the statement.
  - Description—Describes the function of the configuration statement.
  - Options—Describes the configuration statement's options, if there are any. For options with numeric values, the allowed range and default value, if any, are listed. For multiple options, if one option is the default, that fact is stated. If a configuration statement is at the top of a hierarchy of options that are other configuration statements, these options are generally explained separately in the statement summary section.
  - Usage guidelines—Points to the section or sections in the configuration guidelines section that describe how to use the configuration statement.
  - Required privilege level—Indicates the permissions that the user must have to view or modify the statement in the router configuration. For an explanation of the permissions, see the *JUNOS Internet Software Configuration Guide: Getting Started*.
  - See also—Indicates other configuration statements that might provide related or similar functionality.

Using the Indexes

This manual contains two indexes: a complete index, which contains all index entries, and an index that contains only statements and commands.

In the complete index, bold page numbers point to pages in the statement summary chapters. The index entry for each configuration statement always contains at least two entries. The first, with a bold page number on the same line as the statement name, references the statement summary section. The second entry, "usage guidelines," references the section in a configuration guidelines chapter that describes how to use the statement.

Documentation Conventions

General Conventions

This manual uses the following text conventions:

- Statements, commands, filenames, directory names, IP addresses, and configuration hierarchy levels are shown in a sans serif font. In the following example, *stub* is a statement name and [edit protocols ospf area *area-id*] is a configuration hierarchy level:

  > To configure a stub area, include the stub statement at the [edit protocols ospf area *area-id*] hierarchy level:

- In examples, text that you type literally is shown in bold. In the following example, you type the word *show*:

  ```
  [edit protocols ospf area area-id]
  cli# show
  stub <default-metric metric>
  ```

- Examples of command output are generally shown in a fixed-width font to preserve the column alignment. For example:

```
> show interfaces terse
Interface       Admin Link Proto Local             Remote
at-1/3/0        up    up
at-1/3/0.0      up    up   inet  1.0.0.1           --> 1.0.0.2
                           iso
fxp0            up    up
fxp0.0          up    up   inet  192.168.5.59/24
```

Conventions for Software Commands and Statements

When describing the JUNOS software, this manual uses the following type and presentation conventions:

- Statement or command names that you type literally are shown nonitalicized. In the following example, the statement name is *area*:

  > You configure all these routers by including the following area statement at the [edit protocols ospf] hierarchy level:

- Options, which are variable terms for which you substitute appropriate values, are shown in italics. In the following example, *area-id* is an option. When you type the area statement, you substitute a value for *area-id.*

  ```
  area area-id;
  ```

- Optional portions of a configuration statement are enclosed in angle brackets. In the following example, the "default-metric *metric*" portion of the statement is optional:

  ```
  stub <default-metric metric>;
  ```

- For text strings separated by a pipe (|), you must specify either *string1* or *string2*, but you cannot specify both or neither of them. Parentheses are sometimes used to group the strings.

  ```
  string1 | string2
  (string1 | string2)
  ```

  In the following example, you must specify either broadcast or multicast, but you cannot specify both:

  ```
  broadcast | multicast
  ```

- For some statements, you can specify a set of values. The set must be enclosed in square brackets. For example:

  ```
  community name members [community-id]
  ```

- The configuration examples in this manual are generally formatted in the way that they appear when you issue a show command. This format includes braces ({ }) and semicolons. When you type configuration statements in the CLI, you do not type the braces and semicolons. However, when you type configuration statements in an ASCII file, you must include the braces and semicolons. For example:

  ```
  [edit]
  cli# set routing-options static route default nexthop address retain
  [edit]
  cli# show
  routing-options {
      static {
          route default {
              nexthop address;
              retain;
          }
      }
  }
  ```

- Comments in the configuration examples are shown either preceding the lines that the comments apply to, or more often, they appear on the same line. When comments appear on the same line, they are preceded by a pound sign (#) to indicate where the comment starts. In an actual configuration, comments can only precede a line; they cannot be on the same line as a configuration statement. For example:

  ```
  protocols {
      mpls {
          interface (interface-name | all);    # Required to enable MPLS on the interface
      }
      rsvp {                                   # Required for dynamic MPLS only
          interface interface-name;
      }
  }
  ```

- The general syntax descriptions provide no indication of the number of times you can specify a statement, option, or keyword. This information is provided in the text of the statement summary.

List of Technical Publications

Table 1 lists the software and hardware books for Juniper Networks routers and describes the contents of each book.

Table 1: Juniper Networks Technical Documentation

Book	Description
JUNOS Internet Software Configuration Guides	
Getting Started	Provides an overview of the JUNOS Internet software and describes how to install and upgrade the software. This manual also describes how to configure system management functions and how to configure the chassis, including user accounts, passwords, and redundancy.
Interfaces and Class of Service	Provides an overview of the interface and class-of-service functions of the JUNOS Internet software and describes how to configure the interfaces on the router.
MPLS Applications	Provides an overview of traffic engineering concepts and describes how to configure traffic engineering protocols.
Multicast	Provides an overview of multicast concepts and describes how to configure multicast routing protocols.
Network Management	Provides an overview of network management concepts and describes how to configure various network management features, such as SNMP, accounting options, and cflowd.
Policy Framework	Provides an overview of policy concepts and describes how to configure routing policy, firewall filters, and forwarding options.
Routing and Routing Protocols	Provides an overview of routing concepts and describes how to configure routing, routing instances, and unicast routing protocols.
VPNs	Provides an overview of Layer 2 and Layer 3 Virtual Private Networks (VPNs), describes how to configure VPNs, and provides configuration examples.
JUNOS Internet Software References	
Operational Mode Command Reference	Describes the JUNOS Internet software operational mode commands you use to monitor and troubleshoot Juniper Networks routers.
System Log Messages Reference	Describes how to access and interpret system log messages generated by JUNOS software modules and provides a reference page for each message.
JUNOScript API Documentation	
JUNOScript API Guide	Describes how to use the JUNOScript API to monitor and configure Juniper Networks routers.
JUNOScript API Reference	Provides a reference page for each tag in the JUNOScript API.
JUNOS Internet Software Comprehensive Index	
Comprehensive Index	Provides a complete index of all JUNOS Internet software books and the *JUNOScript API Guide*.
Hardware Documentation	
Hardware Guide	Describes how to install, maintain, and troubleshoot routers and router components. Each router platform (M5 and M10 routers, M20 router, M40 router, M40e router, M160 router, and T640 routing node) has its own hardware guide.
PIC Guide	Describes the router Physical Interface Cards (PICs). Each router platform has its own PIC guide.

Documentation Feedback

We are always interested in hearing from our customers. Please let us know what you like and do not like about the Juniper Networks documentation, and let us know of any suggestions you have for improving the documentation. Also, let us know if you find any mistakes in the documentation. Send your feedback to tech-doc@juniper.net.

How to Request Support

For technical support, contact Juniper Networks at support@juniper.net, or at 1-888-314-JTAC (within the United States) or 408-745-2121 (from outside the United States).

Part 1

VPN Overview

Chapter 1

VPN Overview

A virtual private network (VPN) consists of two topological areas, the provider's network and the customer's network. The provider's network, which runs across the public Internet infrastructure, consists of routers that provide VPN services to a customer's network as well as routers that provide other services. The customer's network is commonly located at multiple physical sites. The provider's network acts to connect the various customer sites in what appears to the customer and the provider to be a private network.

To ensure that VPNs remain private and isolated from other VPNs and from the public Internet, the provider's network maintains policies that keep routing information from different VPNs separate.

A provider can service multiple VPNs as long as its policies keep routes from different VPNs separate. Similarly, a site can belong to multiple VPNs as long as it keeps routes from the different VPNs separate.

VPN Terminology

VPNs contain the following types of network devices (see Figure 1):

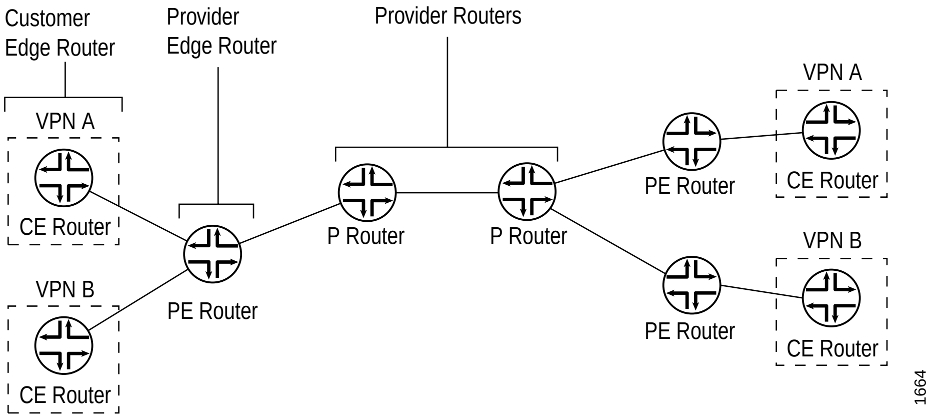
- Provider edge (PE) routers—Routers in the provider's network that connect to CE devices located at customer sites. PE routers support VPN and label functionality. (The label functionality can be provided either by RSVP or LDP.) Within a single VPN, pairs of PE routers are connected through a tunnel, which can be either an MPLS LSP or an LDP tunnel.

- Provider (P) routers—Routers within the core of the provider's network that are not connected to any routers at a customer site but that are part of the tunnel between pairs of PE routers. Provider routers support MPLS LSP or LDP functionality, but do not need to support VPN functionality.

- Customer edge (CE) devices—Routers or switches located at the customer's site that connect to the provider's network. CE devices are typically IP routers.

VPN functionality is provided by the PE routers; the provider and CE routers have no special configuration requirements for VPNs.

Figure 1: VPN Router Components



Differences between Layer 2 and Layer 3 VPNs

In a Layer 3 VPN, the routing occurs on the service provider's routers. In a Layer 2 VPN, routing occurs on the customer's routers, typically on the customer edge (CE) router. Layer 3 VPNs require more configuration on the part of the service provider, because the service provider's PE routers must know the customer's routes. Layer 2 VPNs require less configuration on the part of the service provider, because routing is handled by the customer's routers and not the service provider's.

Part 2
Layer 2 VPNs

Chapter 2
Layer 2 VPN Overview

This chapter provides an overview of Layer 2 Multiprotocol Label Switching (MPLS) virtual private networks (VPNs) as they are implemented in the JUNOS software.

For information about VPNs as they are implemented in the JUNOS software and also information on the differences between Layer 2 and Layer 3 VPNs, see "VPN Overview" on page 3.

This chapter discusses the following topics:

- Layer 2 VPN Overview on page 7
- Layer 2 VPN Standards on page 8

Layer 2 VPN Overview

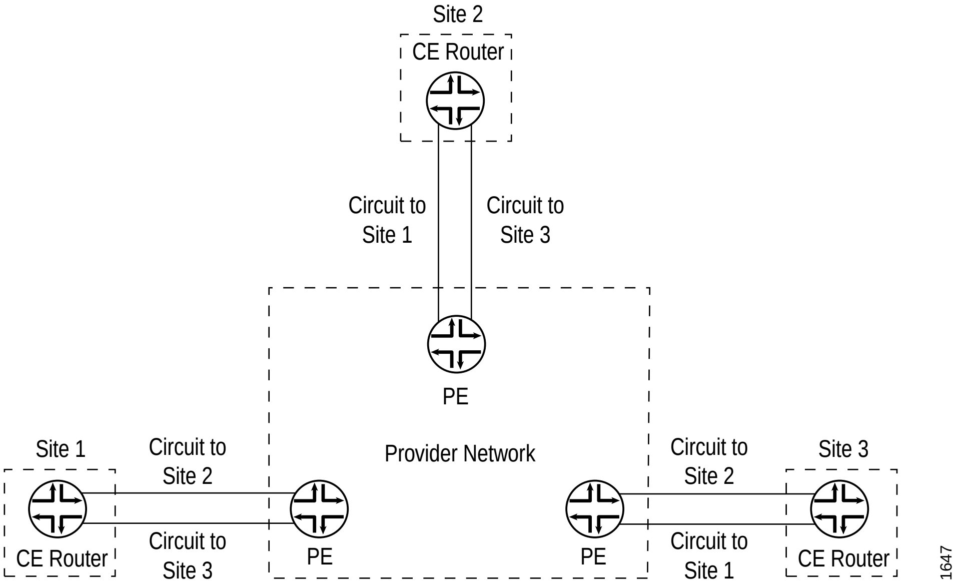
Implementing a Layer 2 VPN on a router is similar to implementing a VPN using a Layer 2 technology such as ATM or Frame Relay. However, for a Layer 2 VPN on a router, traffic is forwarded to the router in a Layer 2 format. It is carried by MPLS over the service provider's network, and then converted back to Layer 2 format at the receiving site. You can configure different Layer 2 formats at the sending and receiving sites. The security and privacy of an MPLS Layer 2 VPN are equal to those of an ATM or Frame Relay VPN.

On a Layer 2 VPN, routing occurs on the customer's routers, typically on the customer edge (CE) router. The CE router connected to a service provider on a Layer 2 VPN must select the appropriate circuit on which to send traffic. The provider edge (PE) router receiving the traffic sends it across the service provider's network to the PE router connected to the receiving site. PE routers do not need to know the customer's routes or routing topology; they need to know only in which tunnel to send the data.

For a Layer 2 VPN, customers need to configure their own routers to carry all Layer 3 traffic. The service provider needs to know only how much traffic the Layer 2 VPN will need to carry. The service provider's routers carry traffic between the customer's sites using Layer 2 VPN interfaces. The VPN topology is determined by policies configured on the PE routers.

Customers need to know only which VPN interfaces connect to which of their own sites. Figure 2 illustrates a Layer 2 VPN in which each site has a VPN interface linked to each of the other customer sites.

Figure 2: Layer 2 VPN Connecting CE Routers



The benefits of implementing a Layer 2 MPLS VPN include:

- Service providers do not have to invest in separate Layer 2 equipment to provide Layer 2 VPN service. A Layer 2 MPLS VPN allows you to provide Layer 2 VPN service over an existing IP and MPLS backbone.

- You can configure the PE router to run any Layer 3 protocol in addition to the Layer 2 protocols.

- Customers who prefer to maintain control over most of the administration of their own networks might want Layer 2 VPN connections with their service provider instead of a Layer 3 VPN.

Layer 2 VPN Standards

For more information about Layer 2 VPNs, see:

- *MPLS-based Layer 2 VPNs*, Internet draft draft-kompella-ppvpn-l2vpn.

You can access Internet RFCs and drafts from the IETF Web site at http://www.ietf.org.

Chapter 3
Layer 2 VPN Configuration Guidelines

To configure Layer 2 virtual private network (VPN) functionality, you must enable Layer 2 VPN support on the provider edge (PE) router. You must also configure PE routers to distribute routing information to the other PE routers in the VPN and configure the circuits between the PE routers and the customer edge (CE) routers.

Each Layer 2 VPN is configured under a routing instance of type l2vpn. An l2vpn routing instance can transparently carry Layer 3 traffic across the service provider's network. As with other routing instances, all logical interfaces belonging to a Layer 2 VPN routing instance are listed under that instance.

The configuration of the CE routers is not relevant to the service provider. The CE routers only need to provide appropriate Layer 2 circuits (with appropriate circuit identifiers, such as Data-Link Connection Identifier [DLCI], Virtual Path Identifier/Virtual Circuit Identifier [VPI/VCI], or Virtual Local Area Network Identifier [VLAN ID]) to send traffic to the PE router.

To configure Layer 2 VPNs, you include statements at the [edit routing-instances *routing-instance-name*] hierarchy level:

```
[edit]
routing-instances {
    routing-instance-name {
        description text;
        instance-type l2vpn;
        interface interface-name;
        route-distinguisher (as-number:id | ip-address:id);
        vrf-export [ policy-name ];
        vrf-import [ policy-name ];
        protocols {
            l2vpn {
                encapsulation type
                traceoptions {
                    file filename <replace> <size size> <files number> <nostamp>;
                    flag flag <flag-modifier> <disable>;
                }
                site site-name {
                    site-identifier identifier;
                    interface interface-name {
                        remote-site-id remote-site-ID;
                    }
                }
            }
        }
    }
}
```

For Layer 2 VPNs, only some of the statements in the [edit routing-instances] hierarchy are valid. For the full hierarchy, see the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

In addition to these statements, you must configure Multiprotocol Label Switching (MPLS) label-switched paths (LSPs) between the PE routers, Internal Border Gateway Protocol (IBGP) sessions between the PE routers, and an Interior Gateway Protocol (IGP) on the PE and provider routers.

By default, Layer 2 VPNs are disabled.

This chapter describes the following tasks for configuring Layer 2 VPNs:

- Configure MPLS LSPs between the PE Routers on page 10
- Configure an IGP on the PE Routers on page 13
- Configure an IBGP Session between PE Routers on page 14
- Configure Routing Instances for Layer 2 VPNs on the PE Routers on page 14
- Configure the Connections to the Local Site on page 19

Configure MPLS LSPs between the PE Routers

For Layer 2 VPNs to function, you must configure MPLS LSPs between the PE routers. You can do one of the following:

- Configure MPLS LSPs using LDP on page 10
- Configure MPLS LSPs Using RSVP on page 12

Configure MPLS LSPs using LDP

To use the Label Distribution Protocol (LDP) to configure the MPLS LSPs, perform the following steps on the PE and provider routers:

1. Configure LDP on the interfaces in the core of the service provider’s network by including the ldp statement at the [edit protocols] hierarchy level. You need to configure LDP only on the interfaces between PE routers or between PE and provider routers. You can think of these as the “core-facing” interfaces.

```
[edit]
protocols {
    ldp {
        interface interface-name;
    }
}
```

2. Configure the MPLS address family on the interfaces on which you enabled LDP (the interfaces you configured in Step 1):

   ```
   [edit]
   interfaces {
       interface-name {
           unit logical-unit-number {
               family mpls;
           }
       }
   }
   ```

   Specify the interface name in the format *type-fpc/pic/port*.

3. Configure OSPF or IS-IS on each PE and provider router. You configure these protocols at the master instance of the routing protocol, not within the routing instance used for the VPN.

   To configure OSPF, include the ospf statement at the [edit protocols] hierarchy level. At a minimum, you must configure a backbone area on at least one of the router's interfaces.

   ```
   [edit]
   protocols {
       ospf {
           area 0.0.0.0 {
               interface interface-name;
           }
       }
   }
   ```

   To configure IS-IS, include the isis statement at the [edit protocols] hierarchy level and configure the loopback interface and ISO family at the [edit interfaces] hierarchy level. At a minimum, you must enable IS-IS on the router, configure a network entity title (NET) on one of the router's interfaces (preferably the loopback interface, lo0), and configure the ISO family on all interfaces on which you want IS-IS to run. When you enable IS-IS, Level 1 and Level 2 are enabled by default. The following is the minimum IS-IS configuration. In the address statement, *address* is the NET.

   ```
   [edit]
   interfaces {
       lo0 {
           unit logical-unit-number {
               family iso {
                   address address;
               }
           }
       }
       type-fpc/pic/port {
           unit logical-unit-number {
               family iso;
           }
       }
   }
   protocols {
       isis {
           interface all;
       }
   }
   ```

For detailed information about how to configure LDP, see the *JUNOS Internet Software Configuration Guide: MPLS Applications*. For more information about configuring OSPF and IS-IS, see the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

Configure MPLS LSPs Using RSVP

To configure the MPLS LSPs using RSVP, perform the following steps:

1. On each PE router, configure traffic engineering. To do this, you must configure an IGP that supports traffic engineering (either IS-IS or OSPF) and enable traffic engineering support for that protocol.

   To enable OSPF traffic engineering support, include the traffic-engineering statement at the [edit protocols ospf] hierarchy level:

   ```
   [edit protocols ospf]
   traffic-engineering;
   ```

   For IS-IS, traffic engineering support is enabled by default.

2. On each PE and provider router, enable RSVP on the router interfaces that participate in the label-switched path (LSP). On the PE router, these are the interfaces that are the ingress and egress points to the LSP. On the provider router, these are the interfaces that connect the LSP between the PE routers.

   To configure RSVP on the PE and provider routers, include the interface statement at the [edit rsvp] hierarchy level. Include one interface statement for each interface on which you are enabling RSVP.

   ```
   [edit]
   rsvp {
       interface interface-name;
       interface interface-name;
   }
   ```

3. On each PE router, configure an MPLS LSP to the PE router that is the LSP's egress point. To do this, include the label-switched-path and interface statements at the [edit mpls] hierarchy level.

   ```
   [edit]
   mpls {
       label-switched-path lsp-path-name {
           to ip-address;
       }
       interface interface-name;
   }
   ```

   In the to statement, specify the address of the LSP's egress point, which is an address on the remote PE router.

   In the interface statement, specify the name of the interface (both the physical and logical portions). Include one interface statement for the interface associated with the LSP.

When you configure the same interface at the [edit interfaces] hierarchy level, you must also configure family mpls and family inet when configuring the logical interface:

```
[edit interfaces]
interface-name {
    unit logical-unit-number {
        family inet;
        family mpls;
    }
}
```

4. On all provider routers that participate in the LSP, enable MPLS by including the interface statement at the [edit mpls] hierarchy level. Include one interface statement for each connection to the LSP.

    ```
    [edit]
    mpls {
        interface interface-name;
        interface interface-name;
    }
    ```

5. Enable MPLS on the interface between the PE and CE routers by including the interface statement at the [edit mpls] hierarchy level. Doing this allows the PE router to assign an MPLS label to traffic entering the LSP or to remove the label from traffic exiting the LSP.

    ```
    [edit]
    mpls {
        interface interface-name;
    }
    ```

For information about configuring RSVP or MPLS, see the *JUNOS Internet Software Configuration Guide: MPLS Applications*.

Configure an IGP on the PE Routers

To allow PE routers to exchange routing information, you must configure either an IGP or static routes on these routers. You configure the IGP on the master instance of the routing protocol process at the [edit protocols] hierarchy level, not within the routing instance used for the Layer 2 VPN—that is, not at the [edit routing-instances] hierarchy level.

When you configure the PE router, do not configure any summarization of the PE router’s loopback addresses at the area boundary. Each PE router’s loopback address should appear as a separate route.

For information about configuring routing protocols and static routes, see the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

Configure an IBGP Session between PE Routers

You must configure an IBGP session between PE routers to allow these routers to exchange information about Layer 2 VPNs, particularly information about sites connected to Layer 2 VPNs. The PE routers rely on this information to determine which labels to use for traffic destined for remote sites. To enable an IBGP session between the PE routers, include the family l2vpn statement when configuring IBGP in the master instance:

```
[edit protocols bgp]
bgp {
    group group-name {
        type internal;
        local-address ip-address;
        family l2vpn {
            unicast;
        }
        neighbor ip-address;
    }
}
```

The family l2vpn statement indicates that the IBGP session is for the Layer 2 VPN.

The IP address in the local-address statement is the same as the address configured in the to statement at the [edit protocols mpls label-switched-path *lsp-path-name*] hierarchy level on the remote PE router. The IBGP session uses this address as the source in the peering session.

The IP address in the neighbor statement is the loopback address of the neighboring PE router. If you are using RSVP signaling, this IP address is the same address you specify in the to statement at the [edit mpls label-switched-path *lsp-path-name*] hierarchy level when you configure the MPLS LSP.

Configure Routing Instances for Layer 2 VPNs on the PE Routers

To configure routing instances for Layer 2 VPNs, include the routing-instances statement at the [edit] hierarchy level. You configure Layer 2 VPN routing instances only on the PE routers.

Configure the routing instance as follows:

```
[edit]
routing-instances {
    routing-instance-name {
        description text;
        instance-type l2vpn;
        interface interface-name;
        route-distinguisher (as-number:id | ip-address:id);
        vrf-export [ policy-name ]
        vrf-import [ policy-name ]
    }
}
```

> Note
>
> For the Layer 2 VPN to function, you must include the instance-type, interface, route-distinguisher, vrf-export, and vrf-import statements in the routing instance configuration on the PE router.

The following sections describe how to configure Layer 2 VPN routing instances:

- Configure the Description on page 15
- Configure the Instance Type on page 15
- Configure Interfaces for Layer 2 VPN Routing on page 15
- Configure CCC Encapsulation on Interfaces on page 16
- Configure TCC Encapsulation on Interfaces on page 17
- Configure Layer 2 VPN Policing on Interfaces on page 18
- Configure the Route Distinguisher on page 19
- Configure Policy for the PE Router’s VRF Table on page 19

Configure the Description

To provide a textual description for the routing instance, include the description statement at the [edit routing-instances *routing-instance-name*] hierarchy level. Enclose any descriptive text that includes spaces in quotation marks (" "). Any descriptive text you include is displayed in the output of the show route instance detail command and has no effect on the operation of the routing instance.

```
[edit routing-instances routing-instance-name]
description text;
```

Configure the Instance Type

To enable Layer 2 VPN routing on a PE router, include the instance-type statement at the [edit routing-instances *routing-instance-name*] hierarchy level, specifying the instance type as l2vpn:

```
[edit routing-instances routing-instance-name]
instance-type l2vpn;
```

Configure Interfaces for Layer 2 VPN Routing

On each PE router, you must configure the interfaces over which the Layer 2 VPN traffic travels between PE and CE routers. To do this, include the interface statement at the [edit routing-instances *routing-instance-name*] hierarchy level:

```
[edit routing-instances routing-instance-name]
interface interface-name;
```

Specify both the physical and logical portions of the interface name, in the following format:

```
physical.logical
```

For example, in at-1/2/1.2, at-1/2/1 is the physical portion of the interface name and 2 is the logical portion. If you do not specify the logical portion of the interface name, 0 is set by default.

A logical interface can be associated with only one routing instance.

Note

If you enable a routing protocol on all instances by specifying interfaces all when configuring the master instance of the protocol at the [edit protocols] hierarchy level and if you configure a specific interface for Layer 2 VPN routing at the [edit routing-instances *routing-instance-name*] hierarchy level, the latter interface statement takes precedence and the interface is used exclusively for the Layer 2 VPN.

If you explicitly configure the same interface name at both the [edit protocols] and [edit routing-instances *routing-instance-name*] hierarchy levels, when you try to commit the configuration, it will fail.

Configure CCC Encapsulation on Interfaces

You need to specify a circuit cross-connect (CCC) encapsulation type for each PE-router-to-CE-router interface running a Layer 2 VPN. This encapsulation type should match the encapsulation type configured under the routing instance. See “Configure the Encapsulation Type” on page 21 for information about how to configure the encapsulation type under the routing instance.

To configure the CCC encapsulation type, include the following statements at the [edit interfaces] hierarchy level:

```
[edit]
interfaces {
    interface name {
        encapsulation ccc-encapsulation-type;
        unit unit number {
            encapsulation ccc-encapsulation-type;
        }
    }
}
```

You configure the encapsulation type at the [edit interfaces] hierarchy level differently than you do at the [edit routing-instance] hierarchy level. For example, you specify the encapsulation as frame-relay at the [edit routing-instances] hierarchy level and as frame-relay-ccc at the [edit interfaces] hierarchy level.

You can run both standard Frame Relay and CCC Frame Relay on the same device. If you specify Frame Relay encapsulation (frame-relay-ccc) for the interface, you should also configure the encapsulation at the [edit interfaces *interface name* unit *unit-number*] hierarchy level as frame-relay-ccc. Otherwise, the logical interface unit defaults to standard Frame Relay.

The following are the CCC encapsulation types:

- atm-aal5-ccc—ATM AAL/5
- atm-cell-ccc—ATM cell
- cisco-hdlc-ccc—Cisco Systems-compatible HDLC
- ethernet-vlan-ccc—Ethernet VLAN
- frame-relay-ccc—Frame Relay
- ppp-ccc—PPP

Configure TCC Encapsulation on Interfaces

Translation cross-connect (TCC) encapsulation types allow you to configure a different encapsulation type at the ingress and egress of a Layer 2 VPN. For example, a CE router at the ingress of a Layer 2 VPN circuit can send traffic as Frame Relay. A CE router at the egress of that circuit can receive the traffic as ATM.

The configuration for TCC encapsulation types is similar to the configuration for CCC encapsulation types. Specify a TCC encapsulation type for each PE-router-to-CE-router interface running a Layer 2 VPN. This encapsulation type should match the encapsulation type configured under the routing instance. See “Configure the Encapsulation Type” on page 21 for information about how to configure the encapsulation type under the routing instance.

To configure the TCC encapsulation type, include the following statements at the [edit interfaces] hierarchy level:

```
[edit]
interfaces {
    interface name {
        encapsulation tcc-encapsulation-type;
        unit unit number {
            encapsulation tcc-encapsulation-type;
        }
    }
}
```

You configure the encapsulation type at the [edit interfaces] hierarchy level differently than you do at the [edit routing-instance] hierarchy level. For example, you specify the encapsulation as frame-relay at the [edit routing-instances] hierarchy level and as frame-relay-tcc at the [edit interfaces] hierarchy level.

The following are the TCC encapsulation types:

- atm-aal5-tcc—ATM AAL/5
- atm-cell-tcc—ATM cell
- cisco-hdlc-tcc—Cisco Systems-compatible HDLC
- ethernet-tcc—Ethernet
- extended-vlan-tcc—Ethernet extended VLAN

- frame-relay-tcc—Frame Relay
- ppp-tcc—PPP

Configure Layer 2 VPN Policing on Interfaces

You can use policing to control the amount of traffic flowing over the interfaces servicing a Layer 2 VPN. If policing is disabled on an interface, all the available bandwidth on a Layer 2 VPN tunnel can be used by a single circuit cross-connect (CCC) or translational cross-connect (TCC) interface.

Layer 2 VPNs support only input policing. For more information about the policer statement, see the *JUNOS Internet Software Configuration Guide: Policy Framework*.

If you configure CCC encapsulation, then include the policer statement at the [edit interfaces *interface-name* unit *unit-number* family ccc] hierarchy level to enable Layer 2 VPN policing on an interface:

```
[edit]
interfaces interface-name {
    encapsulation encapsulation-type;
    unit 0 {
        family ccc {
            policer {
                input input-name;
            }
        }
    }
}
```

If you configure TCC encapsulation, then include the policer statement at the [edit interfaces *interface-name* unit *unit-number* family tcc] hierarchy level to enable Layer 2 VPN policing on an interface:

```
[edit]
interfaces interface-name {
    encapsulation encapsulation-type;
    unit 0 {
        family tcc {
            policer {
                input input-name;
            }
        }
    }
}
```

For information about how to configure the encapsulation type, see “Configure the Encapsulation Type” on page 21.

Configure the Route Distinguisher

Each routing instance that you configure on a PE router must have a unique route distinguisher associated with it. Layer 2 VPNs need a route distinguisher to help BGP distinguish overlapping NLRIs from different VPNs. Layer 3 VPNs need a route distinguisher for the same purpose.

We recommend that you use unique route distinguishers for each routing instance that you configure. Although you can use the same route distinguisher on all PE routers in the same Layer 2 VPN, if you use a unique route distinguisher, you can determine the PE router from which a route originated.

To configure a route distinguisher on a PE router, include the route-distinguisher statement at the [edit routing-instances *routing-instance-name*] hierarchy level:

```
[edit routing-instances routing-instance-name]
route-distinguisher (as-number:number | ip-address:number);
```

The route distinguisher is a 6-byte value that you can specify in one of the following formats:

- *as-number*:*number*, where *as-number* is an AS number (a 2-byte value) and *number* is any 4-byte value. The AS number can be in the range 1 through 65,535. We recommend that you use an IANA-assigned, nonprivate AS number, preferably the ISP’s own or the customer’s own AS number.

- *ip-address*:*number*, where *ip-address* is an IP address (a 4-byte value) and *number* is any 2-byte value. The IP address can be any globally unique unicast address. We recommend that you use the address that you configure in the router-id statement, which is a nonprivate address in your assigned prefix range.

Configure Policy for the PE Router’s VRF Table

For information about configuring the VRF table, see “Configure Policy for the PE Router’s VRF Table” on page 80.

Configure the Connections to the Local Site

For each local site, the PE router advertises a set of VPN labels to the other PE routers servicing the Layer 2 VPN. The VPN labels constitute a single block of contiguous labels; however, to allow for reprovisioning, more than one such block can be advertised. Each label block consists of a label base, a range (the size of the block), and a remote site ID that identifies the sequence of remote sites that connect to the local site using this label block (the remote site ID is the first site identifier in the sequence). The encapsulation type is also advertised along with the label block.

To configure the connections to the local site on the PE router, perform the following tasks:

- Configure the Local Site on page 20
- Configure the Encapsulation Type on page 21
- Trace Layer 2 VPN Traffic and Operations on page 21

Configure the Local Site

All of the Layer 2 circuits provisioned for a local site are listed as the set of logical interfaces (using the interface statement) within the site statement.

On each PE router, you must configure each site that has a circuit to the PE router. To do this, include the site statement at the [edit routing-instances *routing-instance-name* protocols l2vpn] hierarchy level:

```
[edit routing-instances routing-instance-name protocols l2vpn]
site site-name {
    site-identifier identifier;
    interface interface-name {
        remote-site-id remote-site-ID;
    }
}
```

You must configure the following for each site:

- site—Name of the site.
- site-identifier—Unsigned 16-bit number greater than zero that uniquely identifies the site.
- interface—A name for the interface and, optionally, a remote site ID for remote site connections.

Under the interface statement, you can set a remote site ID, which identifies the remote site to which this interface connects. Be aware of the order of the interfaces because this determines which remote site each interface connects to. The order of the interfaces is based on the interface’s site identifier.

The remote-site-id statement is optional; if omitted, the remote site ID for an interface is automatically set to 1 higher than the remote site ID for the previous interface. For example, if the first interface in the list does not have a remote site ID, its offset is set to 1. The second interface in the list has its offset set to 2, and the third has its offset set to 3. The offsets of any interfaces that follow are incremented in the same manner if you do not explicitly configure them.

The remote site ID allows for a sparse Layer 2 VPN topology. When you configure remote site IDs, each site does not have to connect to all other sites in the Layer 2 VPN, making it unnecessary to allocate circuits for all the remote sites. Remote site IDs are particularly important if you configure a topology more complicated than full mesh.

Configure the Encapsulation Type

The encapsulation type you configure at each Layer 2 VPN site varies depending on which Layer 2 protocol you choose to configure. You need to use the same protocol at each Layer 2 VPN site if you configure ethernet-vlan as the encapsulation type. You do *not* need to use the same protocol at each Layer 2 VPN site if you configure any of the following encapsulation types:

- atm-aal5—ATM AAL/5
- atm-cell—ATM cell
- cisco-hdlc—Cisco Systems-compatible HDLC
- frame-relay—Frame Relay
- ppp—PPP

Note that if you configure different protocols at your Layer 2 VPN sites, you need to configure a TCC encapsulation type. For more information, see “Configure TCC Encapsulation on Interfaces” on page 17.

To configure the Layer 2 protocol accepted by the PE router, specify the encapsulation type by including the encapsulation statement at the [edit routing-instances *routing-instance-name* protocols l2vpn] hierarchy level:

```
[edit routing-instances routing-instance-name protocols l2vpn]
encapsulation type
```

Trace Layer 2 VPN Traffic and Operations

To trace Layer 2 VPN protocol traffic, you can specify options in the Layer 2 VPN traceoptions statement at the [edit routing-instances *routing-instance-name* protocols l2vpn] hierarchy level:

```
[edit routing-instances routing-instance-name protocols l2vpn]
traceoptions {
    file filename <replace> <size size> <files number> <nostamp>;
    flag flag <flag-modifier> <disable>;
}
```

The following trace flags display the operations associated with Layer 2 VPNs. Each can carry one or more of the following modifiers:

- all—All Layer 2 VPN tracing options
- connections—Layer 2 VPN connections (events and state changes)
- error—Error conditions
- nlri—Layer 2 VPN advertisements received or sent using BGP
- route—Trace routing information
- topology—Layer 2 VPN topology changes due to reconfiguration or due to advertisements received from other PE routers using BGP

Disable Normal TTL Decrementing for VPNs

To diagnose networking problems related to VPNs (Layer 2 or Layer 3), it can be useful to disable normal TTL decrementing. In JUNOS, you can do this with the no-propagate-ttl and no-decrement-ttl statements. However, when tracing VPN traffic, only the no-propagate-ttl statement is effective.

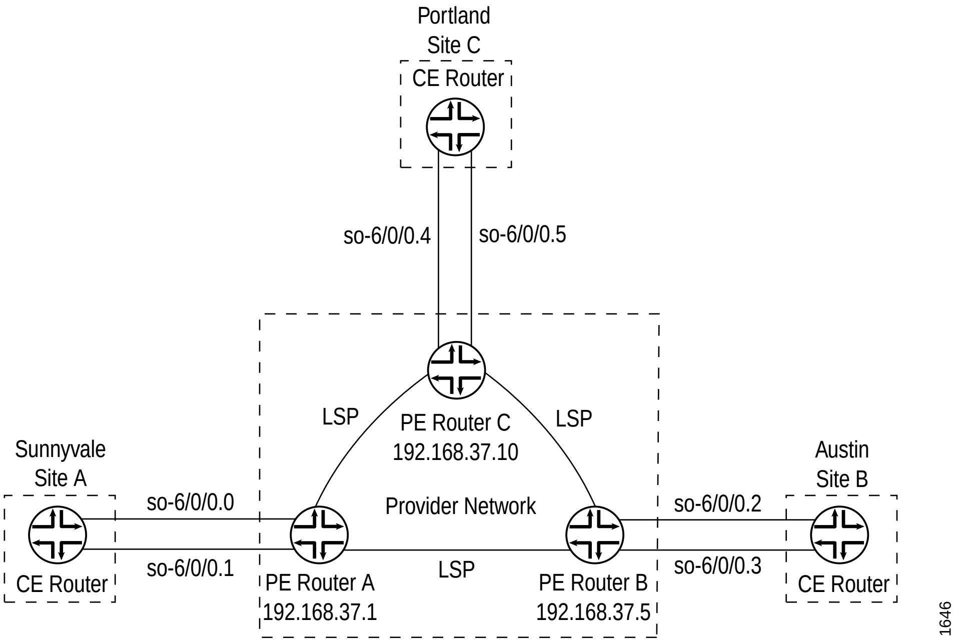
For the no-propagate-ttl statement to have an effect on VPN behavior, you need to clear the PE router-to-PE router BGP session, or disable and then enable the VPN routing instance.

For more information about the no-propagate-ttl and no-decrement-ttl statements, see the *JUNOS Internet Software Configuration Guide: MPLS Applications*.

Chapter 4
Layer 2 VPN Configuration Example

For the example in this chapter, you configure a simple full-mesh Layer 2 virtual private network (VPN) spanning three sites: Sunnyvale, Austin, and Portland. Each site connects to a provider edge (PE) router. The customer edge (CE) routers at each site use Frame Relay to carry Layer 2 traffic to the PE routers. Since this example uses a full-mesh topology between all three sites, each site requires two logical interfaces (one for each of the other CE routers), although only one physical link is needed to connect each PE router to each CE router. Figure 3 illustrates the topology of this Layer 2 VPN.

Figure 3: Example of a Simple Full-Mesh Layer 2 VPN Topology



The following sections explain how to configure Layer 2 VPN functionality on the PE routers connected to each of the sites:

- Enable an IGP on the PE Routers on page 24
- Configure MPLS LSP Tunnels between the PE Routers on page 24
- Configure IBGP on the PE Routers on page 26
- Configure Routing Instances for Layer 2 VPNs on the PE Routers on page 27
- Configure CCC Encapsulation on the Interfaces on page 29
- Configure VPN Policy on the PE Routers on page 30
- Layer 2 VPN Configuration Summarized by Router on page 33

Enable an IGP on the PE Routers

To allow the PE routers to exchange routing information among themselves, you must configure an interior gateway protocol (IGP) or static routes on these routers. You configure the IGP on the master instance of the routing protocol process (rpd) (that is, at the [edit protocols] hierarchy level), not within the Layer 2 VPN routing instance (that is, not at the [edit routing-instances] hierarchy level). Turn on traffic engineering on the IGP.

You configure the IGP in the standard way. This example does not include this portion of the configuration.

Configure MPLS LSP Tunnels between the PE Routers

In this configuration example, RSVP is used for MPLS signaling. Therefore, in addition to configuring RSVP, you must create an MPLS LSP to tunnel the VPN traffic.

On Router A, enable RSVP and configure one end of the MPLS LSP tunnel to Router B. When configuring the MPLS LSP, include all interfaces using the interface all statement.

```
[edit]
protocols {
    rsvp {
        interface all;
    }
    mpls {
        label-switched-path RouterA-to-RouterB {
            to 192.168.37.5;
            primary Path-to-RouterB;
        }
        label-switched-path RouterA-to-RouterC {
            to 192.168.37.10;
            primary Path-to-RouterC;
        }
        interface all;
    }
}
```

On Router B, enable RSVP and configure the other end of the MPLS LSP tunnel. Again, configure the interfaces using the interface all statement.

```
[edit]
protocols {
    rsvp {
        interface all;
    }
    mpls {
        label-switched-path RouterB-to-RouterA {
            to 192.168.37.1;
            primary Path-to-RouterA;
        }
        label-switched-path RouterB-to-RouterC {
            to 192.168.37.10;
            primary Path-to-RouterC;
        }
        interface all;
    }
}
```

On Router C, enable RSVP and configure the other end of the MPLS LSP tunnel. Again, configure all interfaces using the interface all statement.

```
[edit]
protocols {
    rsvp {
        interface all;
    }
    mpls {
            label-switched-path RouterC-to-RouterA {
            to 192.168.37.1;
            primary Path-to-RouterA;
        }
        label-switched-path RouterC-to-RouterB {
            to 192.168.37.5;
            primary Path-to-RouterB;
        }
        interface all;
    }
}
```

Configure IBGP on the PE Routers

On the PE routers, configure an IBGP session with the following parameters:

- Layer 2 VPN—To indicate that the IBGP session is for a Layer 2 VPN, include the family l2vpn statement.

- Local address—The IP address in the local-address statement is the same as the address configured in the to statement at the [edit protocols mpls label-switched-path *lsp-path-name*] hierarchy level. The IBGP session for Layer 2 VPNs runs through this address.

- Neighbor address—Include the neighbor statement, specifying the IP address of the neighboring PE router.

On Router A, configure IBGP as follows:

```
[edit]
protocols{
    bgp {
        import match-all;
        export match-all;
        group pe-pe {
            type internal;
            neighbor 192.168.37.5 {
                local-address 192.168.37.1;
                family l2vpn {
                    unicast;
                }
            }
            neighbor 192.168.37.10 {
                local-address 192.168.37.1;
                family l2vpn {
                    unicast;
                }
            }
        }
    }
```

On Router B, configure IBGP as follows:

```
[edit]
protocols{
    bgp {
        local-address 192.168.37.5;
        import match-all;
        export match-all;
        group pe-pe {
            type internal;
            neighbor 192.168.37.1 {
                local-address 192.168.37.5;
                family l2vpn {
                    unicast;
                }
            }
```

```
                neighbor 192.168.37.10 {
                    local-address 192.168.37.5;
                    family l2vpn {
                        unicast;
                    }
                }
            }
        }
    }
```

On Router C, configure IBGP as follows:

```
[edit]
protocols{
    bgp {
        local-address 192.168.37.10;
        import match-all;
        export match-all;
        group pe-pe {
            type internal;
            neighbor 192.168.37.1 {
                local-address 192.168.37.10;
                family l2vpn {
                    unicast;
                }
            }
            neighbor 192.168.37.5 {
                local-address 192.168.37.10;
                family l2vpn {
                    unicast;
                }
            }
        }
    }
}
```

Configure Routing Instances for Layer 2 VPNs on the PE Routers

The three PE routers service the Layer 2 VPN, so you need to configure a routing instance on each router. For the VPN, you must define the following in each routing instance:

- Route distinguisher, which must be unique for each routing instance on the PE router. It is used to distinguish the addresses in one VPN from those in another VPN.
- Instance type of l2vpn, which configures the router to run a Layer 2 VPN.
- Interfaces connected to the CE routers.
- VRF import and export policies, which must be the same on each PE router that services the same VPN and are used to control the network topology. Unless the import policy contains only a then reject statement, it must include a reference to a community. Otherwise, when you attempt to commit the configuration, the commit fails.

On Router A, configure the following routing instances for the Layer 2 VPN:

```
[edit]
routing-instances {
    VPN-Sunnyvale-Portland-Austin {
        instance-type l2vpn;
        interface so-6/0/0.0;
        interface so-6/0/0.1;
        route-distinguisher 100:1;
        vrf-import vpn-SPA-import;
        vrf-export vpn-SPA-export;
        protocols {
            l2vpn {
            encapsulation-type frame-relay;
                site Sunnyvale {
                    site-identifier 1;
                    interface so-6/0/0.0 {
                        remote-site-id 2;
                    }
                    interface so-6/0/0.1 {
                        remote-site-id 3;
                    }
                }
            }
        }
    }
}
```

On Router B, configure the following routing instance:

```
[edit]
routing-instances {
    VPN-Sunnyvale-Portland-Austin {
        instance-type l2vpn;
        interface so-6/0/0.2;
        interface so-6/0/0.3;
        route-distinguisher 100:1;
        vrf-import vpn-SPA-import;
        vrf-export vpn-SPA-export;
        protocols {
            l2vpn {
                encapsulation-type frame-relay;
                site Austin {
                    site-identifier 2;
                    interface so-6/0/0.2 {
                        remote-site-id 1;
                    }
                    interface so-6/0/0.3 {
                        remote-site-id 3;
                    }
                }
            }
        }
    }
}
```

On Router C, configure the following routing instance for the Layer 2 VPN:

```
[edit]
routing-instances {
    VPN-Sunnyvale-Portland-Austin {
        instance-type l2vpn;
        interface so-6/0/0.4;
        interface so-6/0/0.5;
        route-distinguisher 100:1;
        vrf-import vpn-SPA-import;
        vrf-export vpn-SPA-export;
        protocols {
            l2vpn {
                encapsulation-type frame-relay;
                site Portland {
                    site-identifier 3;
                    interface so-6/0/0.4 {
                        remote-site-id 1;
                    }
                    interface so-6/0/0.5 {
                        remote-site-id 2;
                    }
                }
            }
        }
    }
}
```

Configure CCC Encapsulation on the Interfaces

You need to specify a circuit cross-connect (CCC) encapsulation type for each PE-router-to-CE-router interface running in the Layer 2 VPN. This encapsulation type should match the encapsulation type configured under the routing instance.

Configure the following CCC encapsulation types for the interfaces on Router A:

```
[edit]
interfaces {
    interface so-6/0/0.0 {
        encapsulation frame-relay-ccc;
        unit 0 {
            encapsulation frame-relay-ccc;
        }
    }
    interface so-6/0/0.1 {
        encapsulation frame-relay-ccc;
        unit 1 {
            encapsulation frame-relay-ccc;
        }
    }
}
```

Configure the following CCC encapsulation types for the interfaces on Router B:

```
[edit]
interfaces {
    interface so-6/0/0.2 {
        encapsulation frame-relay-ccc;
        unit 2 {
            encapsulation frame-relay-ccc;
        }
    }
    interface so-6/0/0.3 {
        encapsulation frame-relay-ccc;
        unit 3 {
            encapsulation frame-relay-ccc;
        }
    }
}
```

Configure the following CCC encapsulation types for the interfaces on Router C:

```
[edit]
interfaces {
    interface so-6/0/0.4 {
        encapsulation frame-relay-ccc;
        unit 4 {
            encapsulation frame-relay-ccc;
        }
    }
    interface so-6/0/0.5 {
        encapsulation frame-relay-ccc;
        unit 5 {
            encapsulation frame-relay-ccc;
        }
    }
}
```

Configure VPN Policy on the PE Routers

You must configure VPN import and export policies on each of the PE routers so that they install the appropriate routes in their Virtual Routing and Forwarding (VRF) tables, which they use to forward packets within the VPN.

On Router A, configure the following VPN import and export policies:

```
[edit]
policy-options {
    policy-statement match-all {
        term acceptable {
            then accept;
        }
    }
    policy-statement vpn-SPA-export {
        term a {
            then {
                community add SPA-com;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement vpn-SPA-import {
        term a {
            from {
                protocol bgp;
                community SPA-com;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    community SPA-com members target:69:100;
}
```

On Router B, configure the following VPN import and export policies:

```
[edit]
policy-options {
    policy-statement match-all {
        term acceptable {
            then accept;
        }
    }
    policy-statement vpn-SPA-import {
        term a {
            from {
                protocol bgp;
                community SPA-com;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpn-SPA-export {
        term a {
            then {
                community add SPA-com;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community SPA-com members target:69:100;
}
```

On Router C, configure the following VPN import and export policies:

```
[edit]
policy-options {
    policy-statement match-all {
        term acceptable {
            then accept;
        }
    }
    policy-statement vpn-SPA-import {
        term a {
            from {
                protocol bgp;
                community SPA-com;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpn-SPA-export {
        term a {
            then {
                community add SPA-com;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community SPA-com members target:69:100;
}
```

To apply the VPN policies on the routers, include the vrf-export and vrf-import statements when you configure the routing instance. The VRF import and export policies handle the route distribution across the IBGP session running between the PE routers.

To apply the VPN policies on Router A, include the following statements:

```
[edit]
routing-instances {
    VPN-Sunnyvale-Portland-Austin {
        vrf-import vpn-SPA-import;
        vrf-export vpn-SPA-export;
    }
}
```

To apply the VPN policies on Router B, include the following statements:

```
[edit]
routing-instances {
VPN-Sunnyvale-Portland-Austin {
        vrf-import vpn-SPA-import;
        vrf-export vpn-SPA-export;
        }
}
```

To apply the VPN policies on Router C, include the following statements:

```
[edit]
routing-instances {
VPN-Sunnyvale-Portland-Austin {
        vrf-import vpn-SPA-import;
        vrf-export vpn-SPA-export;
    }
}
```

Layer 2 VPN Configuration Summarized by Router

Summary for Router A (PE Router for Sunnyvale)

Routing Instance for VPN

```
routing-instances {
    VPN-Sunnyvale-Portland-Austin{
        instance-type l2vpn;
        interface so-6/0/0.0;
        interface so-6/0/0.1;
        route-distinguisher 100:1;
        vrf-import vpn-SPA-import;
        vrf-export vpn-SPA-export;
```

Configure Layer 2 VPN

```
    protocols {
        l2vpn {
            encapsulation-type frame-relay;
            site Sunnyvale {
                site-identifier 1;
                interface so-6/0/0.0;
                interface so-6/0/0.1;
            }
        }
    }
```

Configure CCC Encapsulation Types for Interfaces

```
interfaces {
    interface so-6/0/0.0 {
        encapsulation frame-relay-ccc;
        unit 0 {
            encapsulation frame-relay-ccc;
        }
    }
    interface so-6/0/0.1 {
        encapsulation frame-relay-ccc;
        unit 1 {
            encapsulation frame-relay-ccc;
        }
    }
}
```

Master Protocol Instance

```
protocols {
```

Enable RSVP

```
    rsvp {
        interface all;
    }
```

Configure MPLS LSPs

```
mpls {
    label-switched-path RouterA-to-RouterB {
        to 192.168.37.5;
        primary Path-to-RouterB {
            cspf;
        }
    }
    label-switched-path RouterA-to-RouterC {
        to 192.168.37.10;
        primary Path-to-RouterC {
            cspf;
        }
    }
    interface all;
}
```

Configure IBGP

```
bgp {
    import match-all;
    export match-all;
    group pe-pe {
        type internal;
        neighbor 192.168.37.5 {
            local-address 192.168.37.1;
            family l2vpn {
                unicast;
            }
        }
        neighbor 192.168.37.10 {
            local-address 192.168.37.1;
            family l2vpn {
                unicast;
            }
        }
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement match-all {
        term acceptable {
            then accept;
        }
    }
    policy-statement vpn-SPA-export {
        term a {
            then {
                community add SPA-com;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement vpn-SPA-import {
        term a {
            from {
                protocol bgp;
                community SPA-com;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    community SPA-com members target:69:100;
}
```

Summary for Router B (PE Router for Austin)

Routing Instance for VPN

```
routing-instances {
    VPN-Sunnyvale-Portland-Austin {
        instance-type l2vpn;
        interface so-6/0/0.2;
        interface so-6/0/0.3;
        route-distinguisher 100:1;
        vrf-import vpn-SPA-import;
        vrf-export vpn-SPA-export;
```

Configure Layer 2 VPN

```
        protocols {
            l2vpn {
                encapsulation-type frame-relay;
                site Austin {
                    site-identifier 2;
                    interface so-6/0/0.2;
                    interface so-6/0/0.3;
                }
            }
        }
    }
}
```

Configure CCC Encapsulation Types for Interfaces

```
[edit]
interfaces {
    interface so-6/0/0.2 {
        encapsulation frame-relay-ccc;
        unit 2 {
            encapsulation frame-relay-ccc;
        }
    }
    interface so-6/0/0.3 {
        encapsulation frame-relay-ccc;
        unit 3 {
            encapsulation frame-relay-ccc;
        }
    }
}
```

Master Protocol Instance

```
protocols {
```

Enable RSVP

```
    rsvp {
        interface all;
    }
```

Configure MPLS LSPs

```
    mpls {
        label-switched-path RouterB-to-RouterA {
            to 192.168.37.1;
            primary Path-to-RouterA{
                cspf;
            }
        }
        label-switched-path RouterB-to-RouterC {
            to 192.168.37.10;
            primary Path-to-RouterC {
                cspf;
            }
        }
        interface all;
    }
```

Configure IBGP

```
bgp {
    local-address 192.168.37.5;
    import match-all;
    export match-all;
    group pe-pe {
        type internal;
        neighbor 192.168.37.1 {
            local-address 192.168.37.5;
            family l2vpn {
                unicast;
            }
        }
        neighbor 192.168.37.10 {
            local-address 192.168.37.5;
            family l2vpn {
                unicast;
            }
        }
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement match-all {
        term acceptable {
            then accept;
        }
    }
    policy-statement vpn-SPA-import {
        term a {
            from {
                protocol bgp;
                community SPA-com;
            }
            then accept;
        }
        term b {
             then reject;
        }
    }
    policy-statement vpn-SPA-export {
        term a {
            then {
                community add SPA-com;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community SPA-com members target:69:100;
}
```

Summary for Router C (PE Router for Portland)

Routing Instance for VPN

```
routing-instances {
    VPN-Sunnyvale-Portland-Austin {
    instance-type l2vpn;
    interface so-6/0/0.3;
    interface so-6/0/0.4;
    route-distinguisher 100:1;
    vrf-import vpn-SPA-import;
    vrf-export vpn-SPA-export;
```

Configure Layer 2 VPN

```
    protocols {
        l2vpn {
            encapsulation-type frame-relay;
            site Portland {
                site-identifier 3;
                interface so-6/0/0.3;
                interface so-6/0/0.4;
            }
        }
    }
```

Configure CCC Encapsulation Types for Interfaces

```
[edit]
interfaces {
    interface so-6/0/0.4 {
        encapsulation frame-relay-ccc;
        unit 4 {
            encapsulation frame-relay-ccc;
        }
    }
    interface so-6/0/0.5 {
        encapsulation frame-relay-ccc;
        unit 5 {
            encapsulation frame-relay-ccc;
        }
    }
}
```

Master Protocol Instance

```
protocols {
```

Enable RSVP

```
    rsvp {
        interface all;
    }
```

Configure MPLS LSPs

```
mpls {
    label-switched-path RouterC-to-RouterA {
        to 192.168.37.1;
        primary Path-to-RouterA {
            cspf;
        }
    }
    label-switched-path RouterC-to-RouterB {
        to 192.168.37.5;
        primary Path-to-RouterB {
            cspf;
        }
    }
    interface all;
    }
}
```

Configure IBGP

```
bgp {
    local-address 192.168.37.10;
    import match-all;
    export match-all;
    group pe-pe {
        type internal;
        neighbor 192.168.37.1 {
            local-address 192.168.37.10;
            family l2vpn {
                unicast;
            }
        }
        neighbor 192.168.37.5 {
            local-address 192.168.37.10;
            family l2vpn {
                unicast;
            }
        }
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement match-all {
        term acceptable {
            then accept;
        }
    }
    policy-statement vpn-SPA-import {
        term a {
            from {
                protocol bgp;
                community SPA-com;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpn-SPA-export {
        term a {
            then {
                community add SPA-com;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community SPA-com members target:69:100;
}
```

Chapter 5

Summary of Layer 2 VPN Configuration Statements

The following sections explain the major routing-instances configuration statements that apply specifically to Layer 2 virtual private networks (VPNs). The statements are organized alphabetically. Routing instances and the statements at the [edit routing-instances *routing-instance-name* protocols] hierarchy level are explained in the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

description

Syntax description *text*;

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description Allows you to provide a textual description of the routing instance. Enclose any descriptive text that includes spaces in quotation marks (" "). Any descriptive text you include is displayed in the output of the show route instance detail command and has no effect on the operation of the routing instance.

Usage Guidelines See “Configure the Description” on page 15.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

encapsulation

You configure two encapsulation types: one for CCC encapsulation types on interfaces, and one for the Layer 2 protocol on the routing instance.

encapsulation (CCC and TCC)

Syntax encapsulation *type*

Hierarchy Level [edit interfaces *interface name* encapsulation]

Description Layer 2 protocol used for traffic from the customer edge (CE) router. The CCC encapsulation type is configured here. Note that an encapsulation type must also be configured at the [edit routing-instances *routing-instance-name* protocols l2vpn] hierarchy level. The encapsulation types ending in tcc are translation cross-connect types, which you can use when you want to configure different encapsulation types at each end of a Layer 2 VPN.

Options *type*—The following Layer 2 CCC encapsulation types are supported:

- atm-aal5-ccc—ATM AAL/5
- atm-cell-ccc—ATM cell
- cisco-hdlc-ccc—Cisco Systems-compatible HDLC
- cisco-hdlc-tcc—Cisco Systems-compatible HDLC
- ethernet-vlan-ccc—Ethernet VLAN
- frame-relay-ccc—Frame Relay
- frame-relay-tcc—Frame Relay
- ppp-ccc—PPP
- ppp-tcc—PPP

You can run both standard Frame Relay and CCC Frame Relay on the same device. If you specify Frame Relay encapsulation (frame-relay-ccc) for the interface, you should also configure the encapsulation at the [edit interfaces *interface name* unit *unit-number*] hierarchy level as frame-relay-ccc. Otherwise, the logical interface unit defaults to standard Frame Relay.

Usage Guidelines See “Configure MPLS LSPs between the PE Routers” on page 10.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

See Also encapsulation (Layer 2 VPN) on page 43

encapsulation (Layer 2 VPN)

Syntax encapsulation *type*

Hierarchy Level [edit routing-instances *routing-instance-name* protocols l2vpn]

Description Layer 2 protocol used for traffic from the CE router.

Options *type*—The following Layer 2 encapsulation types are supported:

- atm-aal5—ATM AAL/5
- atm-cell—ATM cell
- cisco-hdlc—Cisco Systems-compatible HDLC
- ethernet-vlan—Ethernet VLAN
- frame-relay—Frame Relay
- ppp—PPP

Usage Guidelines See “Configure the Encapsulation Type” on page 21.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

See also encapsulation (CCC and TCC) on page 42

instance-type

Syntax instance-type l2vpn;

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description Type of routing instance.

Options l2vpn—Layer 2 VPN instance.

Usage Guidelines See “Configure the Instance Type” on page 15.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

interface

Syntax interface *interface-name*;

Hierarchy Level [edit routing-instances *routing-instance-name*]
[edit routing-instances *routing-instance-name* protocols l2vpn site *site-name*]

Description Interface over which Layer 2 VPN traffic travels between the provider edge (PE) router and the CE router. You configure the interface on the PE router. If the instance type is l2vpn, the interface statement is required.

Options *interface-name*—Name of the interface to configure.

Usage Guidelines See “Configure Interfaces for Layer 2 VPN Routing” on page 15.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

l2vpn

Syntax l2vpn {...}

Hierarchy Level [edit routing-instances *routing-instance-name* instance-type]
[edit routing-instances *routing-instance-name* protocols]

Description Enable a Layer 2 VPN on the routing instance.

Usage Guidelines See “Configure Routing Instances for Layer 2 VPNs on the PE Routers” on page 14.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

remote-site-id

Syntax remote-site-id *remote-site-ID*;

Hierarchy Level [edit routing-instances *routing-instance-name* protocols l2vpn site *site-name* interface *interface-name*]

Description Controls the remote interface to which the interface should connect. The order of the interfaces configured for the site determines the default value if you do not explicitly configure the remote site ID. This statement is optional.

Usage Guidelines See “Configure the Local Site” on page 20.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

route-distinguisher

Syntax route-distinguisher (*ip-address:number* | *as-number:number*);

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description Identifier attached to a route that distinguishes to which VPN it belongs. Each routing instance must have a unique distinguisher associated with it. Each route distinguisher is a 6-byte value.

Options *as-number*:*number*—*as-number* is your assigned autonomous system (AS) number (a 2-byte value) and *number* is any 4-byte value. The AS number can be in the range of 1 through 65,535.

ip-address:*number*—*ip-address* is an IP address in your assigned prefix range (a 4-byte value) and *number* is any 2-byte value. The IP address can be any globally unique unicast address.

Usage Guidelines See “Configure the Route Distinguisher” on page 19.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

site

Syntax

```
site site-name {
    site-identifier identifier;
    interface interface-name {
        remote-site-id remote-site-ID;
    }
}
```

Hierarchy Level [edit routing-instances *routing-instance-name* protocols l2vpn]

Description Specify the site name, site identifier, and interfaces connecting to the site. Allows you to configure a remote site ID for remote sites.

Options interface *interface-name*—Name of the interface.

site-identifier *identifier*—Numerical identifier for the site used as a default reference for the remote site ID.

remote-site-id *remote-site-ID*—(Optional) Control the remote interface to which the interface should connect. The order of the interfaces configured for the site determines the default value if you do not explicitly configure the remote site ID.

site *site-name*—Name of the site.

Usage Guidelines See “Configure the Local Site” on page 20.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

site-identifier

Syntax site-identifier *identifier*;

Hierarchy Level [edit routing-instances *routing-instance-name* protocols l2vpn site *site-name*]

Description The numerical identifier for the site used as a default reference for the remote site ID. It is an unsigned 16-bit number greater than zero.

Usage Guidelines See “Configure the Local Site” on page 20.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

traceoptions

Syntax

```
traceoptions {
    file filename <replace> <size size> <files number> <nostamp>;
    flag flag <flag-modifier> <disable>;
    }
```

Hierarchy Level [edit routing-instances *routing-instance-name* protocols l2vpn]

Description Trace traffic flowing through a Layer 2 VPN.

Options disable—(Optional) Disable the tracing operation. You can use this option to disable a single operation when you have defined a broad group of tracing operations, such as all.

file *filename*—Name of the file to receive the output of the tracing operation. Enclose the name within quotation marks.

files *number*—(Optional) Maximum number of trace files. When a trace file named *trace-file* reaches its maximum size, it is renamed *trace-file*.0, then *trace-file*.1, and so on, until the maximum number of trace files is reached. Then the oldest trace file is overwritten.

If you specify a maximum number of files, you also must specify a maximum file size with the size option.

Range: 2 to 1000
Default: 2 files

flag *flag*—Tracing operation to perform. To specify more than one tracing operation, include multiple flag statements.

- all—All Layer 2 VPN tracing options
- connections—Layer 2 connections (events and state changes)
- error—Error conditions
- nlri—Layer 2 advertisements received or sent by means of BGP
- route—Routing information
- topology—Layer 2 VPN topology changes caused by reconfiguration or advertisements received from other PE routers using BGP

flag-modifier—(Optional) Modifier for the tracing flag. You can specify the following modifier:

- detail—Provide detailed trace information

no stamp—(Optional) Do not place timestamp information at the beginning of each line in the trace file.
Default: If you omit this option, timestamp information is placed at the beginning of each line of the tracing output.

replace—(Optional) Replace an existing trace file if there is one.
Default: If you do not include this option, tracing output is appended to an existing trace file.

size *size*—(Optional) Maximum size of each trace file, in kilobytes (KB), megabytes (MB), or gigabytes (GB). When a trace file named *trace-file* reaches this size, it is renamed *trace-file*.0. When *trace-file* again reaches its maximum size, *trace-file*.0 is renamed *trace-file*.1 and *trace-file* is renamed *trace-file*.0. This renaming scheme continues until the maximum number of trace files is reached. Then the oldest trace file is overwritten.

If you specify a maximum file size, you also must specify a maximum number of trace files with the files option.

Syntax: *x*k to specify KB, *x*m to specify MB, or *x*g to specify GB
Range: 10 KB through the maximum file size supported on your system
Default: 1 MB

Usage Guidelines See "Trace Layer 2 VPN Traffic and Operations" on page 21.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

vrf-export

Syntax vrf-export [*policy-name*];

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description How routes are exported from the local PE router's VRF table (*routing-instance-name*.inet.0) to the remote PE router. If the instance type is vrf, the vrf-export statement is required.

Options You can configure multiple export policies on the PE router.

Usage Guidelines See "Configure Export Policy for the PE Router's VRF Table" on page 82.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

vrf-import

Syntax vrf-import [*policy-name*];

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description How routes are imported into the local PE router's VRF table (*routing-instance-name*.inet.0) from the remote PE router. If the instance type is vrf, the vrf-import statement is required.

Options You can configure multiple import policies on the PE router.

Usage Guidelines See "Configure Import Policy for the PE Router's VRF Table" on page 81.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

Part 3
Layer 3 VPNs

Chapter 6
Layer 3 VPN Overview

The JUNOS software implements Layer 3 BGP/MPLS virtual private networks (VPNs) as defined in RFC 2547 and Internet draft draft-rosen-rfc2547bis (also referred to as RFC 2547bis). This chapter discusses the following topics that provide background information about Layer 3 VPNs:

Layer 3 VPN Overview

In JUNOS, Layer 3 VPNs are based on RFC 2547bis. RFC 2547bis defines a mechanism by which service providers can use their IP backbones to provide VPN services to their customers. A Layer 3 VPN is a set of sites that share common routing information and whose connectivity is controlled by a collection of policies. The sites that make up a Layer 3 VPN are connected over a provider’s existing public Internet backbone.

RFC 2547bis VPNs are also known as BGP/MPLS VPNs because BGP is used to distribute VPN routing information across the provider’s backbone, and MPLS is used to forward VPN traffic across the backbone to remote VPN sites.

Customer networks, because they are private, can use either public addresses or private addresses, as defined in RFC 1918. When customer networks that use private addresses connect to the public Internet infrastructure, the private addresses might overlap with the same private addresses used by other network users. MPLS/BGP VPNs solve this problem by prefixing a VPN identifier to each address from a particular VPN site, thereby creating an address that is unique both within the VPN and within the public Internet. In addition, each VPN has its own VPN-specific routing table that contains the routing information for that VPN only.

Layer 3 VPN Standards

Layer 3 VPNs are defined in the following documents:

- RFC 2547, *BGP/MPLS VPNs*
- *BGP/MPLS VPNs*, Internet draft draft-rosen-rfc2547bis
- RFC 2283, *Multiprotocol Extensions for BGP4*

To access Internet RFCs and drafts, go to the IETF Web site at http://www.ietf.org.

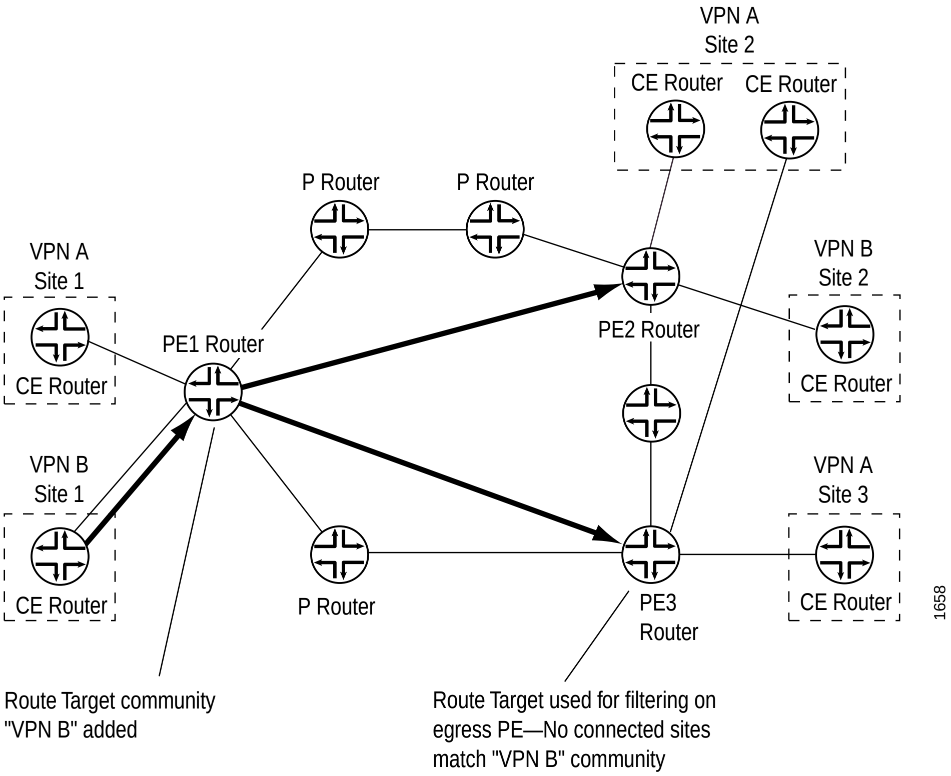
Layer 3 VPN Attributes

Route distribution within a VPN is controlled using BGP extended community attributes. RFC 2547 defines the following three attributes used by VPNs:

- Target VPN—Identifies a set of sites within a VPN to which a PE router distributes routes. This attribute is also called the *route target*. The route target is used by the egress PE router to determine whether a received route is destined for a VPN that the router services.

  Figure 4 illustrates the function of the route target. PE router PE1 adds the route target “VPN B” to routes received from the CE router at Site 1 in VPN B. When it receives the route, the egress router PE2 examines the route target, determines that the route is for a VPN that it services, and accepts the route. When the egress router PE3 receives the same route, it does not accept the route because it does not service any CE routers in VPN B.
- VPN of origin—Identifies a set of sites and the corresponding route as having come from one of the sites in that set.
- Site of origin—Uniquely identifies the set of routes that a PE router learned from a particular site. This attribute ensures that a route learned from a particular site through a particular PE-CE connection is not distributed back to the site through a different PE-CE connection. It is particularly useful if you are using BGP as the routing protocol between the PE and CE routers and if different sites in the VPN have not been assigned distinct AS numbers.

Figure 4: VPN Attributes and Route Distribution

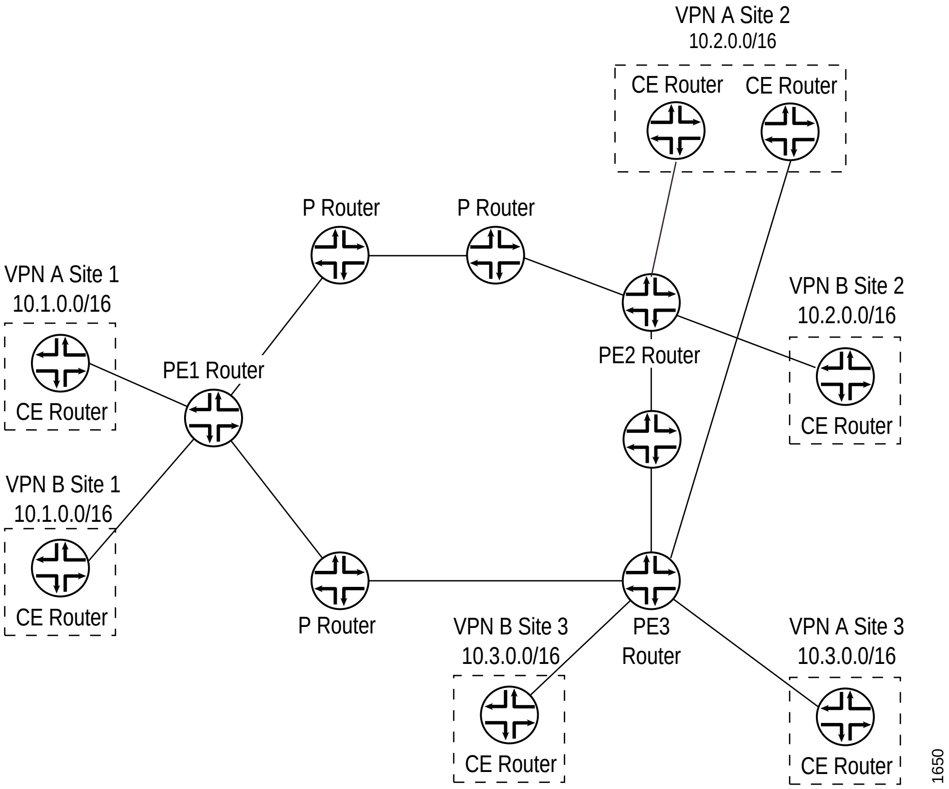


VPN-IPv4 Addresses and Route Distinguishers

Because Layer 3 VPNs connect private networks—which can use either public addresses or private addresses, as defined in RFC 1918—over the public Internet infrastructure, when the private networks use private addresses, the addresses might overlap with the addresses of another private network.

Figure 6 illustrates how private addresses of different private networks can overlap. Here, sites within VPN A and VPN B use the address spaces 10.1.0.0/16, 10.2.0.0/16, and 10.3.0.0/16 for their private networks.

Figure 5: Overlapping Addresses among Different VPNs



To avoid overlapping private addresses, you can configure the network devices to use public addresses instead of private addresses. However, this is a large and complex undertaking. The solution provided in RFC 2547bis uses the existing private network numbers to create a new address that is unambiguous. The new address is part of the VPN-IPv4 address family, which is a BGP address family added as an extension to the BGP protocol. In VPN-IPv4 addresses, a value that identifies the VPN, called a route distinguisher, is prefixed to the private IPv4 address, providing an address that uniquely identifies a private IPv4 address.

Only the PE routers need to support the VPN-IPv4 address extension to BGP. When an ingress PE router receives an IPv4 route from a device within a VPN, it converts it into a VPN-IPv4 route by prefixing the route distinguisher to the route. The VPN-IPv4 addresses are used only for routes exchanged between PE routers. When an egress PE router receives a VPN-IPv4 route, it converts it back to an IPv4 route, by removing the route distinguisher, before announcing the route to its connected CE routers.

VPN-IPv4 addresses have the following format:

- Route distinguisher is a 6-byte value that you can specify in one of the following formats:
    - *as-number*:*number*, where *as-number* is an AS number (a 2-byte value) and *number* is any 4-byte value. The AS number can be in the range 1 through 65,535. We recommend that you use an IANA-assigned, nonprivate AS number, preferably the ISP's own or the customer's own AS number.
    - *ip-address*:*number*, where *ip-address* is an IP address (a 4-byte value) and *number* is any 2-byte value. The IP address can be any globally unique unicast address. We recommend that you use the address that you configure in the router-id statement, which is a nonprivate address in your assigned prefix range.
- IPv4 address—4-byte address of a device within the VPN.

Figure 5 illustrates how the AS number can be used in the route distinguisher. Suppose that VPN A is in AS 65535 and that VPN B is in AS 666 (both these AS numbers belong to the ISP), and suppose that the route distinguisher for Site 2 in VPN A is 65535:02 and that the route distinguisher for Site 2 in VPN B is 666:01. When Router PE2 receives a route from the CE router in VPN A, it converts it from its IP address of 10.2.0.0 to a VPN-IPv4 address of 65535:02:10.2.0.0. When the PE router receives a route from VPN B, which uses the same address space as VPN A, it converts it to a VPN-IPv4 address of 666:02:10.2.0.0.

If the IP address is used in the route distinguisher, suppose the Router PE2's IP address is 172.168.0.1. When the PE router receives a route from VPN A, it converts it to a VPN-IPv4 address of 172.168.0.1:0:10.2.0.0/16, and it converts a route from VPN B to 172.168.0.0:1:10.2.0.0/16.

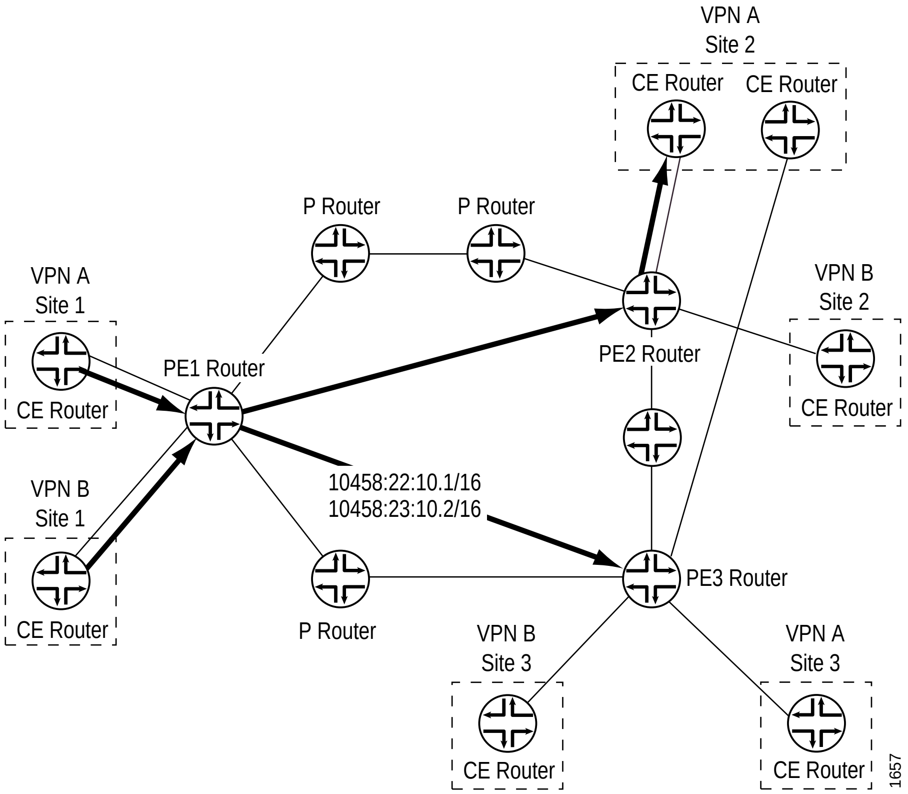
Route distinguishers are used only among PE routers to disambiguate IPv4 addresses from different VPNs. The ingress PE router creates a route distinguisher and converts IPv4 routes received from CE routers into VPN-IPv4 addresses. The egress PE routers convert VPN-IPv4 routes into IPv4 routes before announcing them to the CE router.

Because VPN-IPv4 addresses are a type of BGP address, you must configure IBGP sessions between pairs of PE routers so that the PE routers can distribute VPN-IPv4 routes within the provider's core network. (All PE routers are assumed to be within the same AS.)

You define BGP communities to constrain the distribution of routes among the PE routers. Defining BGP communities does not, by itself, disambiguate IPv4 addresses.

Figure 6 illustrates how Router PE1 adds the route distinguisher 10458:22:10.1/16 to routes received from the CE router at Site 1 in VPN A and forwards these routes to the other two PE routers. Similarly, Router PE1 adds the route distinguisher 10458:23:10.2/16 to routes received by the CE router at Site 1 in VPN B and forwards these routes to the other PE routers.

Figure 6: Route Distinguishers

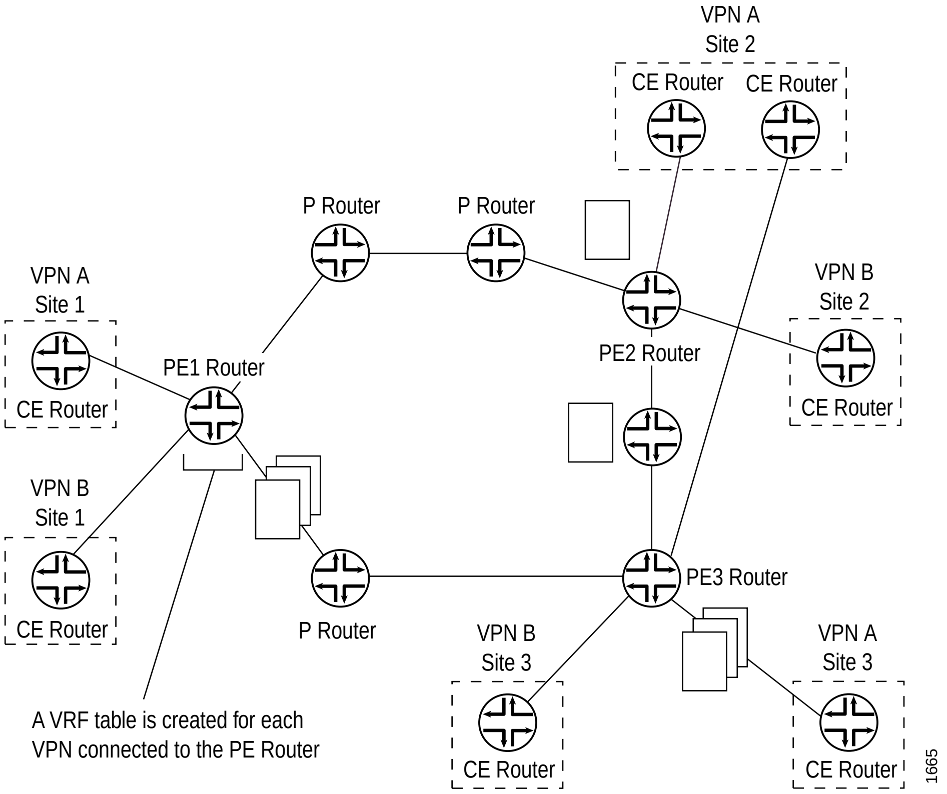


VPN Routing and Forwarding Tables

To separate a VPN’s routes from routes in the public Internet or those in other VPNs, the PE router creates a separate routing table for each VPN, called a VPN Routing and Forwarding (VRF) table. The PE router creates one VRF table for each VPN that has a connection to a CE router. Any customer or site that belongs to the VPN can access only the routes in the VRF tables for that VPN.

Figure 7 illustrates the VRF tables that are created on the PE routers. The three PE routers have connections to CE routers that are in two different VPNs, so each of these PE routers creates two VRF tables, one for each VPN.

Figure 7: VRF Tables



Each VRF table is populated from routes received from directly connected CE sites associated with that VRF and from routes received from other PE routers that passed BGP community filtering and are in the same VPN.

Each PE router also maintains one global routing table (inet.0) to reach other routers in and outside the provider’s core network.

Each customer connection (that is, each logical interface) is associated with one VRF table. Only the VRF table associated with a customer site is consulted for packets from that site.

You can configure the router so that if a next hop to a destination is not found in the VRF table, the router performs a lookup in the global routing table, which is used for Internet access.

The JUNOS software uses the following routing tables for VPNs:

- bgp.l3vpn.0—Stores all VPN-IPv4 unicast routes received from other PE routers. (This table does not store routes received from directly connected CE routers.) This table is present only on PE routers.

  When a PE router receives a route from another PE router, it places the route into its bgp.l3vpn.0 routing table. The route is resolved using the information in the inet.3 routing table. The resultant route is converted into IPv4 format and redistributed to all *routing-instance-name*.inet.0 routing tables on the PE router if it matches the VRF import policy.

  The bgp.l3vpn.0 table is also used to resolve routes over the MPLS tunnels that connect the PE routers. These routes are stored in the inet.3 routing table. PE-PE router connectivity must exist in inet.3 (not just in inet.0) for VPN routes to be resolved properly.

  To determine whether to add a route to the bgp.l3vpn.0 routing table, the JUNOS software checks it against the VRF import policies for all the VPNs configured on the PE router. If the VPN-IPv4 route matches one of the policies, it is added to the bgp.l3vpn.0 table. To display the routes in the bgp.l3vpn.0 routing table, use the show route table bgp.l3vpn.0 command.

- *routing-instance-name*.inet.0—Stores all unicast IPv4 routes received from directly connected CE routers in a routing instance (that is, in a single VPN) and all explicitly configured static routes in the routing instance. This is the VRF table and is present only on PE routers. For example, for a routing instance named VPN-A, the routing table for that instance is named VPN-A.inet.0.

  When a CE router advertises to a PE router, the PE router places the route into the corresponding *routing-instance-name*.inet.0 routing table and advertises the route to other PE routers if it passes a VRF export policy. Among other things, this policy tags the route with the route distinguisher (route target) that corresponds to the VPN site to which the CE belongs. A label is also allocated and distributed with the route. The bgp.l3vpn.0 routing table is not involved in this process.

  The *routing-instance-name*.inet.0 table also stores routes announced by a remote PE router that match the VRF import policy for that VPN. The remote PE router redistributed these routes from its bgp.l3vpn.0 table.

  Routes are not redistributed from the *routing-instance-name*.inet.0 table to the bgp.l3vpn.0 table; they are directly advertised to other PE routers.

  For each *routing-instance-name*.inet.0 routing table, one forwarding table is maintained in the router's Packet Forwarding Engine. This table is maintained in addition to the forwarding tables that correspond to the router's inet.0 and mpls.0 routing tables. As with the inet.0 and mpls.0 routing tables, the best routes from the *routing-instance-name*.inet.0 routing table are placed into the forwarding table.

  To display the routes in the *routing-instance-name*.inet.0 table, use the show route table *routing-instance-name*.inet.0 command.

- inet.3—Stores all MPLS routes learned from LDP and RSVP signaling done for VPN traffic. The routing table stores the MPLS routes only if the traffic-engineering bgp-igp option is not enabled.

  For VPN routes to be resolved properly, the inet.3 table must contain routes to all the PE routers in the VPN.

  To display the routes in the inet.3 table, use the show route inet.3 command.

  Note that IGP shortcuts do not work in VPN environments and should not be configured. IGP shortcuts move routes in inet.3 to inet.0. VPN IBGP (family inet-vpn) relies on next-hops that are in the inet.3 table; thus, IGP shortcuts are incompatible with VPNs.

- inet.0—Stores routes learned by the IBGP sessions between the PE routers. To provide Internet access to the VPN sites, configure the *routing-instance-name*.inet.0 routing table to contain a default route to the inet.0 routing table.

  To display the routes in the inet.0 table, use the show route inet.0 command.

The following routing policies, which are defined in VRF import and export statements, are specific to VRF tables.

- Import policy—Applied to VPN-IPv4 routes learned from another PE router to determine whether the route should be added to the PE router's bgp.l3vpn.0 routing table. Each routing instance on a PE router has a VRF import policy.

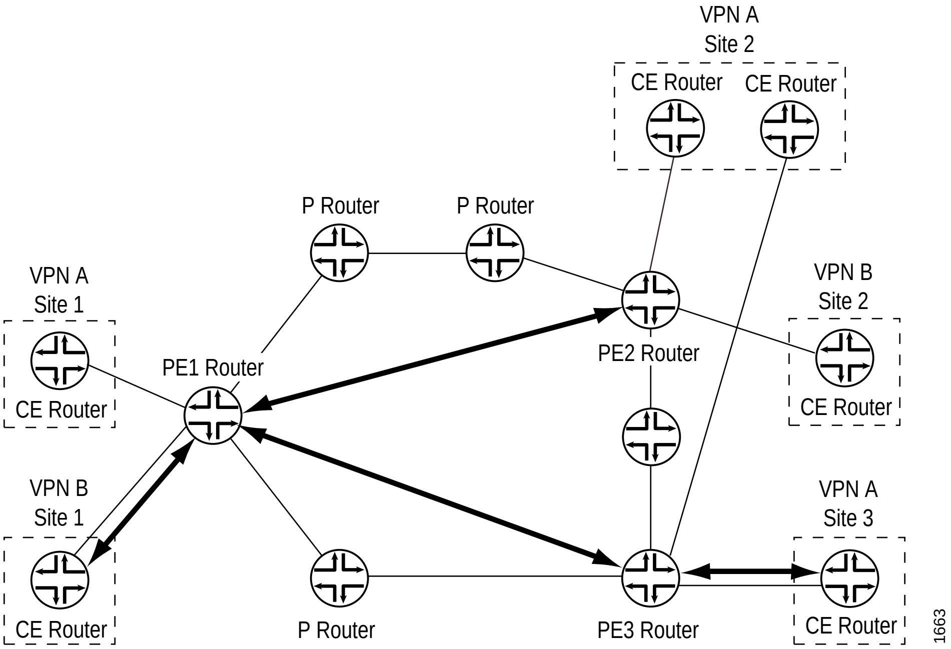
- Export policy—Applied to VPN-IPv4 routes that are announced to other PE routers. The VPN-IPv4 routes are IPv4 routes that have been announced by locally connected CE routers.

VPN route processing differs from normal BGP route processing in one way. In BGP, routes are accepted if they are not explicitly rejected by import policy. However, because many more VPN routes are expected, the JUNOS software does not accept (and hence store) VPN routes unless the route matches at least one VRF import policy. If no VRF import explicitly accepts the route, it is discarded and not even stored in the bgp.l3vpn.0 table. As a result, if a VPN change occurs on a PE router—such as adding a new VRF table or changing a VRF import policy—the PE router sends a BGP route refresh message to the other PE routers (or to the route reflector if this is part of the VPN topology) to retrieve all VPN routes so they can be re-evaluated to determine whether they should be kept or discarded.

Route Distribution within a Layer 3 VPN

Within a VPN, the distribution of VPN-IPv4 routes occurs between the PE and CE routers and between the PE routers (see Figure 8).

Figure 8: Route Distribution within a VPN



This section discusses the following:

- Distribution of Routes from CE to PE Routers on page 61
- Distribution of Routes between PE Routers on page 62
- Distribution of Routes from PE to CE Routers on page 63

Distribution of Routes from CE to PE Routers

A CE router announces its routes to the directly connected PE router. The announced routes are in IPv4 format. The PE router places the routes into the VRF table for the VPN. In the JUNOS software, this is the *routing-instance-name*.inet.0 routing table, where *routing-instance-name* is the configured name of the VPN.

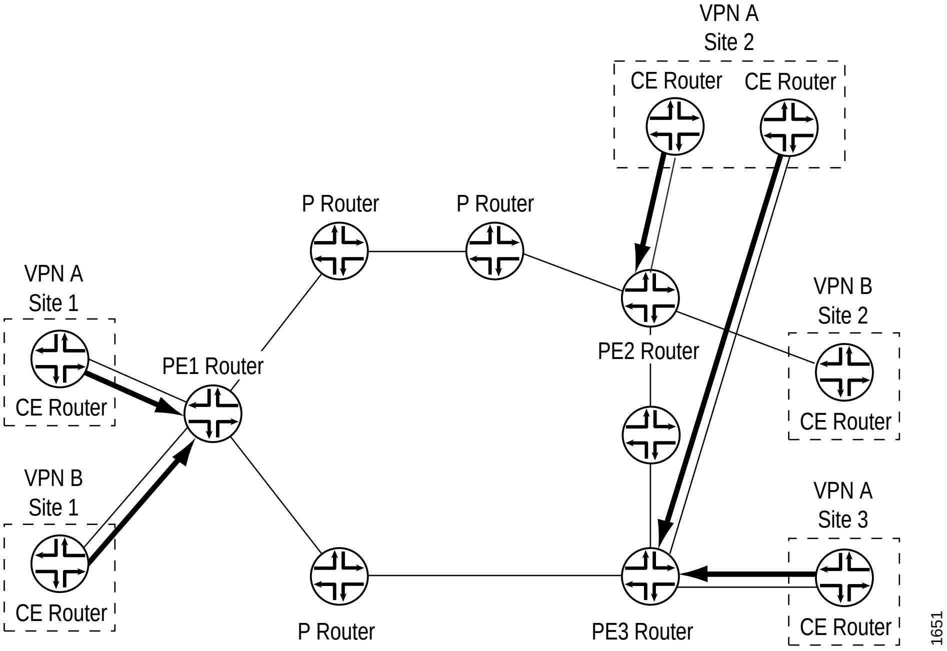
The connection between the CE and PE routers can be a remote connection (a WAN connection) or a direct connection (such as a Frame Relay or Ethernet connection).

CE routers can communicate with PE routers using one of the following:

- OSPF
- RIP
- BGP
- Static route

Figure 9 illustrates how routes are distributed from CE routers to PE routers. Router PE1 is connected to two CE routers that are in different VPNs. Therefore, it creates two VRF tables, one for each VPN. The CE routers announce IPv4 routes. The PE router installs these routes into two different VRF tables, one for each VPN. Similarly, Router PE2 creates two VRF tables into which routes are installed from the two directly connected CE routers. Router PE3 creates one VRF table because it is directly connected to only one VPN.

Figure 9: Distribution of Routes from CE Routers to PE Routers



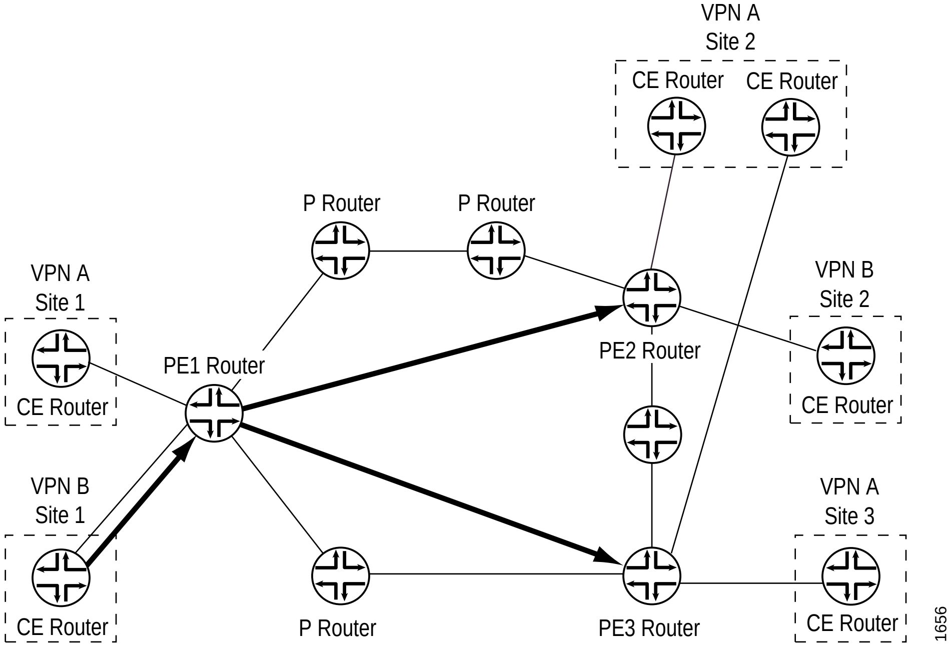
Distribution of Routes between PE Routers

When one PE router receives routes advertised from a directly connected CE router, it checks the received route against the VRF export policy for that VPN. If it matches, the route is converted to VPN-IPv4 format—that is, the route distinguisher (route target) is added to the route. The PE router then announces the route in VPN-IPv4 format to the remote PE routers. The routes are distributed using IBGP sessions, which are configured in the provider's core network. If the route does not match, it is not exported to other PE routers, but can still be used locally for routing, for example, if two CE routers in the same VPN are directly connected to the same PE router.

The remote PE router places the route into its bgp.l3vpn.0 table if the route passes the import policy on the IBGP session between the PE routers. At the same time, it checks the route against the VRF import policy for the VPN. If it matches, the route distinguisher is removed from the route and it is placed into the VRF table (the *routing-instance-name*.inet.0 table) in IPv4 format.

Figure 10 illustrates how Router PE1 distributes routes to the other PE routers in the provider's core network. Router PE2 and Router PE3 each have VRF import policies that they use to determine whether to accept routes received over the IBGP sessions and install them in their VRF tables.

Figure 10: Distribution of Routes between PE Routers



Distribution of Routes from PE to CE Routers

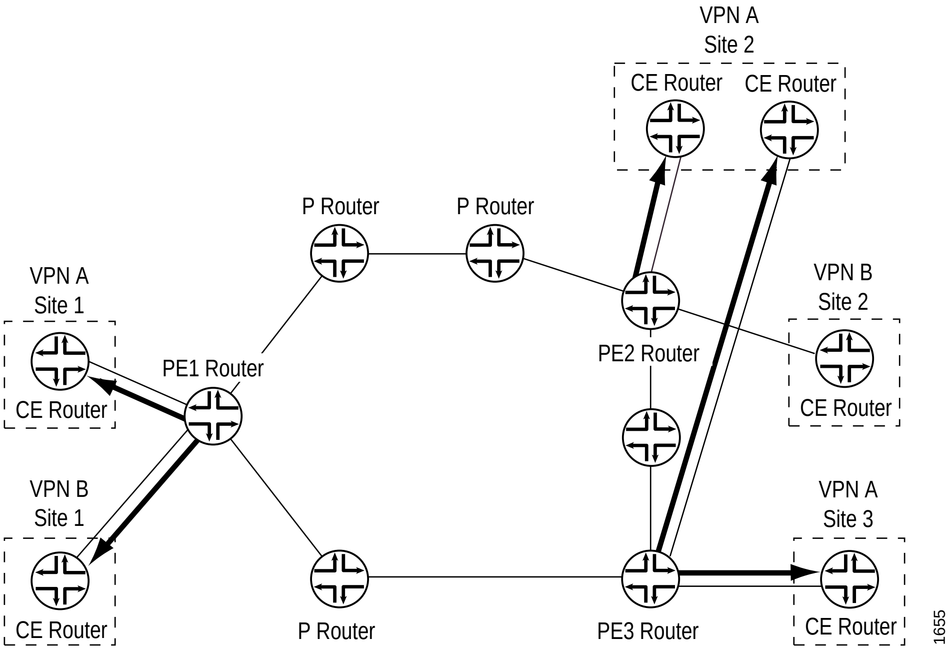
The remote PE router announces the routes in its VRF tables, which are in IPv4 format, to its directly connected CE routers.

PE routers can communicate with CE routers using one of the following routing protocols:

- OSPF
- RIP
- BGP
- Static route

Figure 11 illustrates how the three PE routers announce their routes to their connected CE routers.

Figure 11: Distribution of Routes from PE Routers to CE Routers



Forwarding across the Provider's Core Network

The PE routers in the provider's core network are the only routers that are configured to support VPNs and hence are the only routers that know about the existence of the VPNs. From the point of view of VPN functionality, the provider routers in the core—those provider routers that are not directly connected to CE routers—are merely routers along the tunnel between the ingress and egress PE routers.

The tunnels can be either LDP or MPLS. Any provider routers along the tunnel must support the protocol used for the tunnel, either LDP or MPLS.

When PE-router-to-PE router forwarding is tunneled over MPLS LSPs, the MPLS packets have a two-level label stack (see Figure 12):

- Outer label—Label assigned to the address of the BGP next hop by the IGP next hop
- Inner label—Label that the BGP next hop assigned for the packet's destination address

Figure 12: Using MPLS LSPs to Tunnel between PE Routers

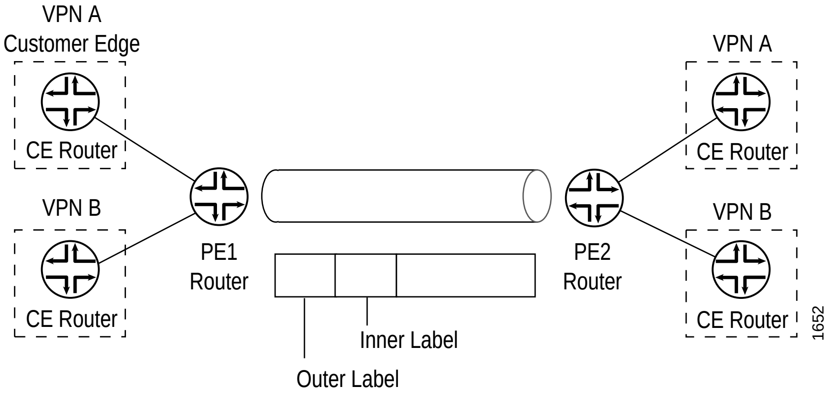


Figure 13 illustrates how the labels are assigned and removed:

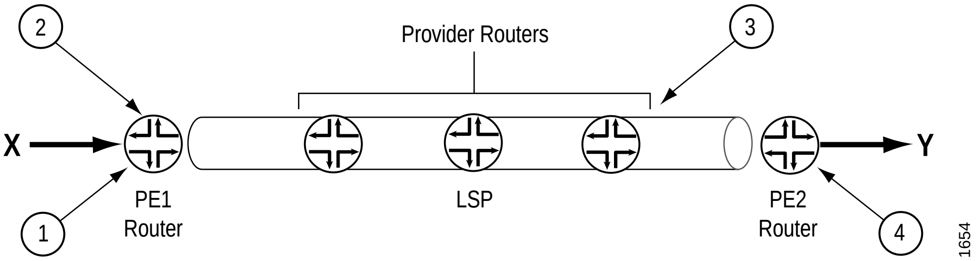
1. When CE Router X forwards a packet to Router PE1 with a destination of CE Router Y, the PE route identifies the BGP next hop to Router Y and assigns a label that corresponds to the BGP next hop and identifies the destination CE router. This label is the inner label.

2. Router PE1 then identifies the IGP route to the BGP next hop and assigns a second label that corresponds to the LSP of the BGP next hop. This label is the outer label.

3. The inner label remains the same as the packet traverses the LSP tunnel. The outer label is swapped at each hop along the LSP and is then popped by the penultimate hop router (the third provider router).

4. Router PE2 pops the inner label from the route and forwards the packet to Router Y.

Figure 13: Label Stack



Routing Instances for VPNs

To implement Layer 3 VPNs in the JUNOS software, you configure one routing instance for each VPN. You configure the routing instances on PE routers only. Each VPN routing instance consists of the following components:

- VRF table—On each PE router, you configure one VRF table for each VPN.
- Set of interfaces that use the VRF table—The logical interface to each directly connected CE router must be associated with a VRF table. You can associate more than one interface with the same VRF table if more than one CE router in a VPN is directly connected to the PE router.
- Policy rules—These control the import of routes into and the export of routes from the VRF table.
- One or more routing protocols that install routes from CE routers into the VRF table—You can use the BGP, OSPF, and RIP routing protocols, and you can use static routes.

Multicast Over Layer 3 VPNs

You can configure multicast routing over a network running a Layer 3 VPN that complies with RFC 2547. This section describes this type of network application, and includes these topics:

Multicast Over Layer 3 VPNs Overview

In the unicast environment of a Layer 3 VPN, all VPN state information is contained within the PE routers. In a multicast Layer 3 VPN environment, Protocol Independent Multicast (PIM) adjacencies are established between the CE router and the PE router and between the master PIM instance. They are configured at the [protocols pim] hierarchy level on the IGP neighbors of the PE router. The set of master PIM adjacencies on the service provider’s network make up the forwarding path, which consists of a rendezvous point (RP) tree rooted at the RP within the service provider’s network.

Therefore, provider (P) routers within the provider network must maintain multicast state information for the Layer 3 VPNs. For this to function, there must be two types of rendezvous points for each VPN:

- The VPN-RP, an RP that resides within the VPN
- The service provider RP (SP-RP), which resides within the service provider network

A PE router can act as an SP-RP, but cannot be the VPN-RP of a Layer 3 VPN. The VPN-RP must be located on a CE router or some other customer router within the VPN.

To configure multicast over a Layer 3 VPN, you must install a Tunnel Services PIC on the following devices:

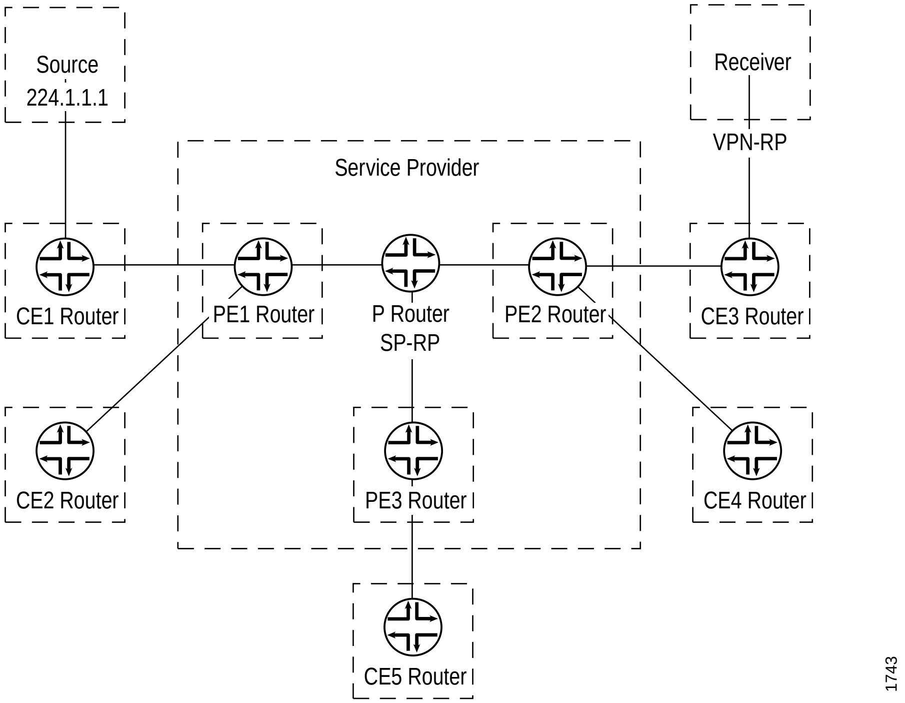
- Provider routers acting as rendezvous points
- PE routers configured to run multicast routing
- CE routers acting as destination routers or as VPN-RPs

For more information about running multicast over Layer 3 VPNs, see the following documents:

- *Multicast in MPLS/BGP VPNs*, Internet draft draft-rosen-vpn-mcast-02.txt
- *JUNOS Internet Software Configuration Guide: Multicast*

The sections that follow describe the operation of a multicast VPN. Figure 14 illustrates the network topology used.

Figure 14: Multicast Topology Overview



Sending PIM Hello Messages to the PE Routers

The first step in initializing multicast over a Layer 3 VPN is the distribution of a PIM Hello message from a PE router (called PE3 in this section) to all the other PE routers on which PIM is configured.

You configure PIM on the Layer 3 VPN routing instance on the PE3 router. If a Tunnel Services PIC exists on the router, a multicast interface is created. This interface is used to communicate between the PIM instance within the VRF and the master PIM instance.

The following occurs when a PIM Hello message is sent to the PE routers:

1. A PIM Hello message is sent from the VRF over the multicast interface. A GRE header is prepended to the PIM Hello message. The header message includes the VPN group address and the loopback address of the PE3 router.

2. A PIM register header is prepended to the Hello message as the packet is looped through the PIM encapsulation interface. This header contains the destination address of the SP-RP and the loopback address of the PE3 router.

3. The packet is sent to the SP-RP.

4. The SP-RP removes the top header from the packet and sends the remaining GRE-encapsulated Hello message to all the PE routers.

5. The master PIM instance on each PE router handles the GRE encapsulated packet. Because the VPN group address is contained in the packet, the master instance removes the GRE header from the packet and sends the Hello message, which contains the proper VPN group address within the VRF, over the multicast interface.

Sending PIM Join Messages to the PE Routers

To receive a multicast broadcast from a multicast network, a CE router must send a PIM Join message to the VPN-RP. The process described in this section refers to Figure 14.

The CE5 router needs to receive a multicast broadcast from multicast source 224.1.1.1. To receive the broadcast, it sends a PIM Join message to the VPN-RP (the PE3 router):

1. The PIM Join message is sent through the multicast interface, and a GRE header is prepended to the message. The GRE header contains the VPN group ID and the loopback address of the PE3 router.

2. The PIM Join message is then sent through the PIM encapsulation interface; a register header is prepended to the packet. The register header contains the IP address of the SP-RP and the loopback address of the PE3 router.

3. The PIM Join message is sent to the SP-RP by means of unicast routing.

4. On the SP-RP, the register header is stripped off (the GRE header remains) and the packet is sent to all the PE routers.

5. The PE2 router receives the packet, and because the link to the VPN-RP is through the PE2 router, it sends the packet through the multicast interface to remove the GRE header.

6. Finally, the PIM Join message is sent to the VPN-RP.

Receiving the Multicast Transmission

The steps that follow outline how a multicast transmission is propagated across the network:

1. The multicast source connected to the CE1 router sends the packet to group 224.1.1.1 (the VPN group address). The packet is encapsulated into a PIM register.

2. Because this packet already includes the PIM header, it is forwarded by means of unicast routing to the VPN-RP over the Layer 3 VPN.

3. The VPN-RP removes the packet and sends it out the downstream interfaces (which include the interface back to the CE3 router). The CE3 router also forwards this to the PE3 router.

4. The packet is sent through the multicast interface on the PE2 router; in the process, the GRE header is prepended to the packet.

5. Next, the packet is sent through the PIM encapsulation interface, where the register header is prepended to the data packet.

6. The packet is then forwarded to the SP-RP, which removes the register header, leaves the GRE header intact, and sends the packet to the PE routers.

7. PE routers remove the GRE header and forward the packet to the CE routers that requested the multicast broadcast by sending the PIM Join message.

> **Note**
>
> PE routers that have not received requests for multicast broadcasts from their connected CE routers still receive packets for the broadcast. These PE routers drop the packets as they are received.

Chapter 7
Layer 3 VPN Configuration Guidelines

To configure Layer 3 virtual private network (VPN) functionality, you must enable VPN support on the provider edge (PE) router. You must also configure any provider (P) routers that service the VPN, and you must configure the customer edge (CE) routers so that their routes are distributed into the VPN.

To configure Layer 3 VPNs, you include statements at the [edit routing-instances] hierarchy level:

```
[edit]
routing-instances {
    routing-instance-name {
        description text;
        interface interface-name;
        instance-type vrf;
        route-distinguisher ( as-number:number | ip-address:number );
        vrf-import [ policy-names ];
        vrf-export [ policy-names ];
        vrf-table-label;
        protocols {
            bgp {
                bgp-configuration;
            }
            ospf {
                ospf-configuration;
            }
            pim {
                pim-configuration;
                vpn-group-address address;
            }
            rip {
                rip-configuration;
            }
        }
        routing-options {
            autonomous-system autonomous-system <loops number>;
            forwarding-table {
                export [ policy-names ];
            }
            interface-routes {
                rib-group group-name;
            }
            martians {
                destination-prefix match-type <allow>;
            }
            maximum-routes route-limit <log-only | threshold value>;
            options {
                syslog (level level | upto level);
            }
            rib routing-table {
                static {
                    defaults {
                        static-options;
                    }
                    route destination-prefix {
                        next-hop;
                        static-options;
                        }
                    }
                }
                martians {
                    destination-prefix match-type <allow>;
                }
                static {
                    defaults {
                        static-options;
                    }
                    route destination-prefix {
                        policy [ policy-names ];
                        static-options;
                    }
                }
            }
            router-id address;
            static {
                defaults {
                    static-options;
                }
                route destination-prefix {
                    policy [ policy-names ];
                    static-options;
                }
            }
        }
    }
}
```

For Layer 3 VPNs, only some of the statements in the [edit routing-instances] hierarchy are valid. For the full hierarchy, see the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

In addition to these statements, you must enable a signaling protocol, Internal Border Gateway Protocol (IBGP) sessions between the PE routers, and an Interior Gateway Protocol (IGP) on the PE and provider routers.

By default, Layer 3 VPNs are disabled.

This chapter describes the following tasks for configuring VPNs:

- Enable a Signaling Protocol on page 73
- Configure an IGP on PE and Provider Routers on page 76
- Configure an IBGP Session between PE Routers on page 77
- Configure Routing Instances for Layer 3 VPNs on PE Routers on page 77
- Configure VPN Routing between the PE and CE Routers on page 85
- Configure Multicast Over Layer 3 VPNs on page 91
- Configure a GRE Tunnel Interface for Layer 3 VPNs on page 91
- Configure an ES Tunnel Interface for Layer 3 VPNs on page 93
- Configure IPSec Between PE Routers Instead of MPLS on page 95

For configuration examples, see “Layer 3 VPN Configuration Examples” on page 111.

Enable a Signaling Protocol

For Layer 3 VPNs to function, you must enable a signaling protocol on the PE routers. You can do one of the following:

- Use LDP for VPN Signaling on page 73
- Use RSVP for VPN Signaling on page 75

Use LDP for VPN Signaling

To use LDP for VPN signaling, perform the following steps on the PE and provider routers:

1. Configure LDP on the interfaces in the core of the service provider’s network by including the ldp statement at the [edit protocols] hierarchy level. You need to configure LDP only on the interfaces between PE routers or between PE and provider routers. You can think of these as the “core-facing” interfaces. You do not need to configure LDP on the interface between the PE and CE routers.

```
[edit]
protocols {
    ldp {
        interface interface-name;
    }
}
```

2. Configure the MPLS address family on the interfaces on which you enabled LDP (the interfaces you configured in Step 1):

   ```
   [edit]
   interfaces {
       interface-name {
           unit logical-unit-number {
               family mpls;
           }
       }
   }
   ```

   Specify the interface name in the format *type-fpc/pic/port*.

3. Configure OSPF or IS-IS on each PE and provider router. You configure these protocols at the master instance of the routing protocol, not within the routing instance used for the VPN.

   To configure OSPF, include the ospf statement at the [edit protocols] hierarchy level. At a minimum, you must configure a backbone area on at least one of the router's interfaces.

   ```
   [edit]
   protocols {
       ospf {
           area 0.0.0.0 {
               interface interface-name;
           }
       }
   }
   ```

   To configure IS-IS, include the isis statement at the [edit protocols] hierarchy level and configure the loopback interface and ISO family at the [edit interfaces] hierarchy level. At a minimum, you must enable IS-IS on the router, configure a network entity title (NET) on one of the router's interfaces (preferably the loopback interface, lo0), and configure the ISO family on all interfaces on which you want IS-IS to run. When you enable IS-IS, Level 1 and Level 2 are enabled by default. The following is the minimum IS-IS configuration. In the address statement, *address* is the NET.

   ```
   [edit]
   interfaces {
       lo0 {
           unit logical-unit-number {
               family iso {
                   address address;
               }
           }
       }
       type-fpc/pic/port {
           unit logical-unit-number {
               family iso;
           }
       }
   }
   protocols {
       isis {
           interface all;
       }
   }
   ```

   For more information about configuring OSPF and IS-IS, see the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

Use RSVP for VPN Signaling

To use RSVP for VPN signaling, perform the following steps:

1. On each PE router, configure traffic engineering. To do this, you must configure an IGP that supports traffic engineering (either IS-IS or OSPF) and enable traffic engineering support for that protocol.

   To enable OSPF traffic engineering support, include the traffic-engineering statement at the [edit protocols ospf] hierarchy level:

   ```
   [edit protocols ospf]
   traffic-engineering {
       no-topology;
       shortcuts;
   }
   ```

   For IS-IS, traffic engineering support is enabled by default.

2. On each PE and provider router, enable RSVP on the router interfaces that participate in the label-switched path (LSP). On the PE router, these are the interfaces that are the ingress and egress points to the LSP. On the provider router, these are the interfaces that connect the LSP between the PE routers. Do not enable RSVP on the interface between the PE and the CE routers, because this interface is not part of the LSP.

   To configure RSVP on the PE and provider routers, include the interface statement at the [edit rsvp] hierarchy level. Include one interface statement for each interface on which you are enabling RSVP.

   ```
   [edit]
   rsvp {
       interface interface-name;
       interface interface-name;
   }
   ```

3. On each PE router, configure an MPLS LSP to the PE router that is the LSP’s egress point. To do this, include the label-switched-path and interface statements at the [edit mpls] hierarchy level.

   ```
   [edit]
   mpls {
       label-switched-path path-name {
           to ip-address;
       }
       interface interface-name;
   }
   ```

   In the to statement, specify the address of the LSP’s egress point, which is an address on the remote PE router.

   In the interface statement, specify the name of the interface (both the physical and logical portions). Include one interface statement for the interface associated with the LSP.

When you configure the same interface at the [edit interfaces] hierarchy level, you must also configure family mpls and family inet when configuring the logical interface:

```
[edit interfaces]
interface-name {
    unit logical-unit-number {
        family inet;
        family mpls;
    }
}
```

4. On all provider routers that participate in the LSP, enable MPLS by including the interface statement at the [edit mpls] hierarchy level. Include one interface statement for each connection to the LSP.

```
[edit]
mpls {
    interface interface-name;
    interface interface-name;
}
```

5. Enable MPLS on the interface between the PE and CE routers by including the interface statement at the [edit mpls] hierarchy level. Doing this allows the PE router to assign an MPLS label to traffic entering the LSP or to remove the label from traffic exiting the LSP.

```
[edit]
mpls {
    interface interface-name;
}
```

For information about configuring MPLS, see the *JUNOS Internet Software Configuration Guide: MPLS Applications*.

Configure an IGP on PE and Provider Routers

To allow the PE and provider routers to exchange routing information, you must either configure an IGP on all the routers or you must configure static routes. You configure the IGP on the master instance of the routing protocol process (rpd) (that is, at the [edit protocols] hierarchy level), not within the routing instance used for the VPN (that is, not at the [edit routing-instances] hierarchy level).

When you configure the PE router, do not configure any summarization of the PE router's loopback addresses at the area boundary. Each PE router's loopback address should appear as a separate route.

For information about configuring routing protocols and static routes, see the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

Configure an IBGP Session between PE Routers

You must configure an IBGP session between PE routers to allow the PE routers to exchange information about routes originating and terminating in the VPN. To do this, include the family inet-vpn statement when configuring IBGP:

```
[edit protocols]
bgp {
    group group-name {
        type internal;
        local-address ip-address;
        family inet-vpn {
            unicast;
        }
        neighbor ip-address;
    }
}
```

The family inet-vpn statement indicates that the IBGP session is for the VPN.

The IP address in the local-address statement is the address of the loopback interface (lo0) on the local PE router. The IBGP session for VPNs runs through the loopback address. (You must also configure the lo0 interface at the [edit interfaces] hierarchy level.)

The IP address in the neighbor statement is the loopback address of the neighboring PE router. If you are using RSVP signaling, this IP address is the same address you specify in the to statement at the [edit mpls label-switched-path *lsp-path-name*] hierarchy level when you configure the MPLS LSP.

Configure Routing Instances for Layer 3 VPNs on PE Routers

To configure routing instances for Layer 3 VPNs, include the routing-instances statement at the [edit] hierarchy level. You configure VPN routing instances only on PE routers.

```
[edit]
routing-instances {
    routing-instance-name {
        description text;
        interface interface-name;
        instance-type vrf;
        route-distinguisher ( as-number:number | ip-address:number );
        vrf-import [ policy-name ];
        vrf-export [ policy-name ];
    }
}
```

Note

For the VPN to function, you must include the instance-type, interface, route-distinguisher, vrf-import, and vrf-export statements in the routing instance configuration on the PE router. The vrf-table-label statement is optional.

The following sections describe how to configure VPN routing instances:

- Configure the Description on page 78
- Configure the Instance Type on page 78
- Configure Interfaces for VPN Routing on page 78
- Configure the Route Distinguisher on page 79
- Configure Policy for the PE Router's VRF Table on page 80

Configure the Description

To provide a textual description for the routing instance, include the description statement at the [edit routing-instances *routing-instance-name*] hierarchy level. Enclose any descriptive text that includes spaces in quotation marks (" "). Any descriptive text you include is displayed in the output of the show route instance detail command and has no effect on the operation of the routing instance.

```
[edit routing-instances routing-instance-name]
description text;
```

Configure the Instance Type

Each PE router uses a VPN Routing and Forwarding (VRF) table for distributing routes within the VPN. To create the VRF table on the PE router, include the instance-type statement at the [edit routing-instances *routing-instance-name*] hierarchy level, specifying the instance type as vrf:

```
[edit routing-instances routing-instance-name]
instance-type vrf;
```

Configure Interfaces for VPN Routing

On each PE router, you must configure an interface over which the VPN traffic travels between the PE and CE routers. To do this, include the interface statement at the [edit routing-instances *routing-instance-name*] hierarchy level:

```
[edit routing-instances routing-instance-name]
interface interface-name;
```

Specify both the physical and logical portions of the interface name, in the following format:

```
physical.logical
```

For example, in so-1/2/1.0, so-1/2/1 is the physical portion of the interface name and 0 is the logical portion. If you do not specify the logical portion of the interface name, 0 is used.

A logical interface can be associated with only one routing instance.

When you configure the same interface at the [edit interfaces] hierarchy level, you must also configure family inet and family mpls when configuring the logical interface:

```
[edit interfaces]
interface-name {
    unit logical-unit-number {
        family inet;
        family mpls;
    }
}
```

> **Note**
>
> If you enable a routing protocol on all instances by specifying interfaces all when configuring the master instance of the protocol at the [edit protocols] hierarchy level, and if you configure a specific interface for VPN routing at the [edit routing-instances *routing-instance-name*] hierarchy level, the latter interface statement takes precedence and the interface is used exclusively for the VPN.
>
> If you explicitly configure the same interface name at both the [edit protocols] and [edit routing-instances *routing-instance-name*] hierarchy levels, when you try to commit the configuration, it will fail.

Configure the Route Distinguisher

Each routing instance that you configure on a PE router must have a unique route distinguisher associated with it. The route distinguisher is used to place bounds around a VPN so the same IP address prefixes can be used in different VPNs without overlapping.

We recommend that you use unique route distinguishers for each routing instance that you configure. Although you can use the same route distinguisher on all PE routers in the same VPN, if you use a unique route distinguisher, you can determine the PE router from which a route originated.

To configure a route distinguisher on a PE router, include the route-distinguisher statement at the [edit routing-instances *routing-instance-name*] hierarchy level:

```
[edit routing-instances routing-instance-name]
route-distinguisher ( as-number:number | ip-address:number );
```

The route distinguisher is a 6-byte value that you can specify in one of the following formats:

- *as-number*:*number*, where *as-number* is an AS number (a 2-byte value) and *number* is any 4-byte value. The AS number can be in the range 1 through 65,535. We recommend that you use an IANA-assigned, nonprivate AS number, preferably the ISP's own or the customer's own AS number.

- *ip-address*:*number*, where *ip-address* is an IP address (a 4-byte value) and *number* is any 2-byte value. The IP address can be any globally unique unicast address. We recommend that you use the address that you configure in the router-id statement, which is a nonprivate address in your assigned prefix range.

Configure Policy for the PE Router’s VRF Table

On each PE router, you must define policies that define how routes are imported into and exported from the router’s VRF table. In these policies, you must define the route target and you can optionally define the route origin.

The following sections describe how to configure policy for the VRF tables:

- Configure the Route Target on page 80
- Configure the Route Origin on page 81
- Configure Import Policy for the PE Router’s VRF Table on page 81
- Configure Export Policy for the PE Router’s VRF Table on page 82
- Filter Traffic Based on the IP Header on page 84
- Configure a VPN Tunnel for VRF Table Lookup on page 85

Configure the Route Target

In the import and export policies for the PE router’s VRF table, you must define the route target, which defines which VPN the route is part of. To do this, include the target option in the community statement at the [edit policy-options] hierarchy level:

```
[edit policy-options]
community name members target:community-id;
```

name is the name of the community.

community-id is the identifier of the community. You specify it in one of the following formats:

- *as-number*:*number*, where *as-number* an AS number (a 2-byte value) and *number* is a 4-byte community identifier. The AS number can be in the range 1 through 65,535. We recommend that you use an IANA-assigned, nonprivate AS number, preferably the ISP’s own or the customer’s own AS number. The community identifier can be a number in the range 0 through $2^{32} - 1$.
- *ip-address*:*number*, where *ip-address* is an IPv4 address (a 4-byte value) and *number* is a 2-byte community identifier. The IP address can be any globally unique unicast address. We recommend that you use the address that you configure in the router-id statement, which is a nonprivate address in your assigned prefix range. The community identifier can be a number in the range 1 through 65,535.

Configure the Route Origin

In the import and export policies for the PE router's VRF table, you can optionally define the route origin (otherwise known as the site of origin), which identifies the set of routes learned from a particular CE site. To do this, include the origin option in the community statement at the [edit policy-options] hierarchy level:

```
[edit policy-options]
community name members origin:community-id;
```

name is the name of the community.

community-id is the identifier of the community. You specify it in one of the following format:

- *as-number*:*number*, where *as-number* an AS number (a 2-byte value) and *number* is a 4-byte community identifier. The AS number can be in the range 1 through 65,535. We recommend that you use an IANA-assigned, nonprivate AS number, preferably the ISP's own or the customer's own AS number. The community identifier can be a number in the range 0 through $2^{32} – 1$.
- *ip-address*:*number*, where *ip-address* is an IPv4 address (a 4-byte value) and *number* is a 2-byte community identifier. The IP address can be any globally unique unicast address. We recommend that you use the address that you configure in the router-id statement, which is a nonprivate address in your assigned prefix range. The community identifier can be a number in the range 1 through 65,535.

Configure Import Policy for the PE Router's VRF Table

Each VPN must have a policy that defines how routes are imported into the PE router's VRF table. An import policy is applied to routes received from other PE routers in the VPN. A policy must evaluate all routes received over the IBGP session with the peer PE router. If the routes match the conditions, the route is installed in the PE router's *routing-instance-name*.inet.0 VRF table. An import policy must contain a second term that rejects all other routes.

Unless an import policy contains only a then reject statement, it must include a reference to a community. Otherwise, when you try to commit the configuration, the commit fails. Note that you can configure multiple import policies.

An import policy determines what to import to a specified VRF table based on the VPN routes learned from the remote PE routers through IBGP. The IBGP session is configured at the [edit protocols bgp] hierarchy level. If you also configure an import policy at the [edit protocols bgp] hierarchy level, the import policies at the [edit policy-options] hierarchy level and the [edit protocols bgp] hierarchy level are combined through a logical AND operation. This allows you to filter traffic as a group.

To configure an import policy for the PE router’s VRF table, follow these steps:

1. To define an import policy, include the policy-statement statement at the [edit policy-options] hierarchy level. For all PE routers, an import policy must always include the following, at a minimum:

   ```
   [edit]
   policy-options {
       policy-statement import-policy-name {
           term import-term-name {
               from {
                   protocol bgp;
                   community community-id;
               }
               then accept;
           }
           term term-name {
               then reject;
           }
       }
   }
   ```

   The *import-policy-name* policy evaluates all routes received over the IBGP session with the other PE router. If the routes match the conditions in the from statement, the route is installed in the PE router’s *routing-instance-name*.inet.0 VRF table. The second term in the policy rejects all other routes.

   For more information about creating policies, see the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

2. To configure an import policy, include the vrf-import statement at the [edit routing-instances *routing-instance-name*] hierarchy level:

   ```
   [edit routing-instances routing-instance-name]
   vrf-import [ import-policy-name ];
   ```

Configure Export Policy for the PE Router’s VRF Table

Each VPN must have a policy that defines how routes are exported from the PE router’s VRF table. An export policy is applied to routes sent to other PE routers in the VPN. An export policy must evaluate all routes received over the routing protocol session with the CE router. (This session can use the BGP, OSPF, or RIP routing protocols, or static routes.) If the routes match the conditions, the specified community target (which is the route target) is added to them and they are exported to the remote PE routers. An export policy must contain a second term that rejects all other routes.

Export policies defined within the VPN routing instance are the only export policies that apply to the VRF table. Any export policy that you define on the IBGP session between the PE routers has no effect on the VRF table. Note that you can configure multiple export policies.

To configure an export policy for the PE router's VRF table, follow these steps:

1. To define an export policy, include the policy-statement statement at the [edit policy-options] hierarchy level. For all PE routers, an export policy must distribute VPN routes to and from the connected CE routers in accordance with the type of routing protocol that you configure between the CE and PE routers within the routing instance. An export policy must always include the following, at a minimum:

   ```
   [edit]
   policy-options {
       policy-statement export-policy-name {
           term export-term-name {
               from protocol (bgp | ospf | rip | static);
               then {
                   community add community-id;
                   accept;
               }
           }
           term term-name {
               then reject;
           }
       }
   }
   ```

   The *export-policy-name* policy evaluates all routes received over the routing protocol session with the CE router. (This session can use either the BGP, OSPF, or RIP routing protocol or static routes.) If the routes match the conditions in the from statement, the community target specified in the then community add statement is added to them and they are exported to the remote PE routers. The second term in the policy rejects all other routes.

   For more information about configuring routing within the routing instance, see "Configure VPN Routing between the PE and CE Routers" on page 85. For more information about creating policies, see the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

2. To apply the policy, include the vrf-export statement at the [edit routing-instances *routing-instance-name*] hierarchy level:

   ```
   [edit routing-instances routing-instance-name]
   vrf-export [ export-policy-name ];
   ```

Filter Traffic Based on the IP Header

The vrf-table-label statement makes it possible to map the inner label to a specific VRF and thus allow the examination of the encapsulated IP header at an egress VPN router. You might want to enable this functionality so you can do either of the following:

- Forward traffic on a PE-router-to-CE-device interface, in a shared medium, where the CE device is a Layer 2 switch without IP capabilities (for example, a metro Ethernet switch).

  The first lookup is done on the VPN label to determine which VRF table to refer to, and the second lookup is done on the IP header to determine how to forward packets to the correct end hosts on the shared medium.

- Perform egress filtering at the egress PE router.

  The first lookup on the VPN label is done to determine which VRF table to refer to, and the second lookup is done on the IP header to determine how to filter and forward packets. You can enable this functionality by configuring output filters on the VRF interfaces.

When you use the vrf-table-label statement to configure a VRF table, a label-switched interface (LSI) logical interface label is created and mapped to the VRF. You perform this configuration at the [edit routing-instances *routing-instance-name*] hierarchy level.

Any routes configured in a VRF with the vrf-table-label statement are advertised with the LSI logical interface label allocated for the VRF. When packets for this VPN arrive on a core-facing interface, they are treated as if the enclosed IP packet arrived on the LSI interface and are then forwarded and filtered based on the correct table.

To filter traffic based on the IP header, include the vrf-table-label statement at the [edit routing-instances routing-instance-name] hierarchy level:

```
[edit routing-instances routing-instance-name]
vrf-table-label;
```

Note: Do not use the vrf-table-label statement for source class usage (SCU)/ destination class usage (DCU) configurations. For information on SCU/DCU configuration, see the *JUNOS Internet Software Configuration Guide: Interfaces and Class of Service.*

Egress Filtering Options and Limitations

Egress filtering (which allows egress Layer 3 VPN PE routers to perform lookups on the VPN label and IP header at the same time) can be enabled by including the vrf-table-label statement at the [edit routing-instances *instance-name*] hierarchy level. However, this feature works only for non-channelized PPP/HDLC core-facing SONET interfaces. There is no restriction on CE-router-to-PE-router interfaces.

You can also enable egress filtering by configuring a VPN tunnel (VT) interface on routers equipped with a Tunnel PIC. When you enable egress filtering this way, there is no restriction on the type of core-facing interface used. There is also no restriction on the type of CE-router-to-PE-router interface used.

> **Note**
>
> You cannot configure a VT interface and the vrf-table-label statement at the same time.

Configure a VPN Tunnel for VRF Table Lookup

You can configure a VPN tunnel to facilitate VRF table lookup based on MPLS labels. You might want to enable this functionality to forward traffic on a PE-router-to-CE-device interface in a shared medium, where the CE device is a Layer 2 switch without IP capabilities (for example, a metro Ethernet switch), or to perform egress filtering at the egress PE router.

For more information on VPN tunnels and VPN tunnel (VT) interfaces, see the *JUNOS Internet Software Configuration Guide: Interfaces and Class of Service*.

Configure VPN Routing between the PE and CE Routers

For the PE router to distribute VPN-related routes to and from connected CE routers, you must configure routing within the VPN routing instance. You can configure a routing protocol—either BGP, OSPF, or RIP—or you can configure static routing. For the connection to each CE router, you can configure only one type of routing.

This section describes how to do the following tasks:

- Configure BGP between the PE and CE Routers on page 85
- Configure OSPF between PE and CE Routers on page 86
- Configure RIP between the PE and CE Routers on page 89
- Configure Static Routes between the PE and CE Routers on page 90
- Limit the Routes Accepted from a CE Router on page 90

Configure BGP between the PE and CE Routers

To configure BGP as the routing protocol between the PE and the CE routers, include the bgp statement at the [edit routing-instances *routing-instance-name* protocols] hierarchy level:

```
[edit routing-instances routing-instance-name protocols]
bgp {
    group group-name {
        peer-as as-number;
        neighbor ip-address;
    }
}
```

Configure OSPF between PE and CE Routers

You can configure OSPF to distribute VPN-related routes between PE and CE routers.

To configure OSPF as the routing protocol between a PE and CE router, include the protocols ospf statement at the [edit routing-instances *routing-instance-name* protocols] hierarchy level:

```
[edit routing-instances routing-instance-name protocols]
ospf {
    area area {
        interface interface-name;
    }
}
```

Configure an OSPF Domain ID

For most OSPF configurations involving Layer 3 VPNs, you do not need to configure an OSPF domain ID. However, for a Layer 3 VPN connecting multiple OSPF domains, configuring OSPF domain IDs can help you to control LSA translation (for Type-3 and Type-5 LSAs) between the OSPF domains and back door paths. The default OSPF domain ID is 0.0.0.0. Each VRF table in a PE router associated with an OSPF instance is configured with the same OSPF domain ID.

When a PE router receives a route, it redistributes and advertises the route either as a Type-3 LSA or as a Type-5 LSA, depending on the following:

- If the receiving PE router sees a Type-3 route with a matching domain ID, the route is redistributed and advertised as a Type-3 LSA.
- If the receiving PE router sees a Type-3 route without a domain ID (the extended attribute field of the route's BGP update does not include a domain ID), the route is redistributed and advertised as a Type-3 LSA.
- If the receiving PE router sees a Type-3 route with a non-matching domain ID, the route is redistributed and advertised as a Type-5 LSA.
- If the receiving PE router sees a Type-3 route with a domain ID but the receiving PE router does not have a domain ID configured, the route is redistributed and advertised as a Type-5 LSA.
- If the receiving PE router sees a Type-5 route, the route is redistributed and advertised as a Type-5 LSA, irrespective of the domain ID.

To configure an OSPF domain ID, include the domain-id statement at the [edit routing-instances *routing-instance-name* protocols ospf] hierarchy level:

```
[edit routing-instances routing-instance-name protocols]
ospf {
    domain-id domain ID;
}
```

You can set a VPN tag for the OSPF external routes generated by the PE router. This is used to prevent looping when a domain ID is used as an alternate route preference. By default, this tag is automatically calculated and needs no configuration. To configure the domain VPN tag for Type 5 LSAs, include the domain-vpn-tag *number* statement at the [edit routing-instances *routing-instance-name* protocols ospf] hierarchy level:

```
[edit routing-instances routing-instance-name protocols]
ospf {
    domain-vpn-tag number;
}
```

The range is 1 through 4,294,967,295. If you set VPN tags manually, you must set the same value for all PE routers in the VPN.

Compatibility with JUNOS Releases before 5.3

For JUNOS release 5.3, the format for domain-id, an extended community type defined in the BGP extended community attribute field, was modified to comply with the IETF draft draft-rosen-vpns-ospf-bgp-mpls (available at http://www.ietf.org/). JUNOS releases prior to 5.3 continue to use the previously supported vendor-specific formats.

The OSPF domain ID format is incompatible between JUNOS 5.3 or later and JUNOS 5.2 or earlier. For OSPF domain IDs to function properly between a PE router running JUNOS 5.3 or later and a PE router running JUNOS 5.2 or earlier, you need to define the extended community type for the BGP extended community attribute field as domain-id-vendor (instead of as domain-id). This is part of the policy-options configuration for the OSPF domain ID configured at the [edit policy-options community vrf_export_attributes members] hierarchy level:

```
[edit policy-options community vrf_export_attributes members]
domain-id-vendor:ip-address
```

You also need to configure the route-type-community statement with the vendor option at the [edit routing-instances *routing-instance-name* protocols ospf] hierarchy level:

```
[edit routing-instances routing-instance-name protocols]
ospf {
    route-type-community vendor;
}
```

The default value for the route-type-community statement is iana.

Example Configurations for Compatibility with JUNOS Releases before 5.3

The following example shows a configuration of the policy options for a PE router. The PE router has an OSPF domain ID configured.

It needs to be compatible with a router running a pre-5.3 version of JUNOS software. As a part of the community statement configuration specify domain-id-vendor for the attribute that assigns the domain ID instead of domain-id:

```
[edit]
policy-options {
    policy-statement vrf_import_routes {
        term a {
            from {
                protocol bgp;
                community vrf_import_attributes;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vrf_export_routes {
        term a {
            from protocol ospf;
            then {
                community add vrf_export_attributes;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vrf_export_attributes members [ target:10.19.2.0:5 domain-id-vendor:1.2.3.4:0 ];
    community vrf_import_attributes members target:10.19.1.0:5;
}
```

The following example shows a configuration for a routing instance on a PE router. The PE router has an OSPF domain ID configured. It needs to be compatible with a router running an earlier version of JUNOS software. The configuration includes the route-type-community statement with the vendor option. This is so the PE router receiving the route knows how to parse the incoming BGP attribute field containing the domain ID.

The example configuration follows:

```
[edit]
routing-instances {
    CE_A {
        instance-type vrf;
        interface fe-1/0/0.0;
        route-distinguisher 10.255.25.270:1;
        vrf-import vrf_import_routes;
        vrf-export vrf_export_routes;
        protocols {
            ospf {
                route-type-community vendor;
                domain-id 1.2.3.4;
                export vrf_import_routes;
                area 0.0.0.0 {
                    interface fe-1/0/0.0;
                }
            }
        }
    }
}
```

Configure RIP between the PE and CE Routers

For a Layer 3 VPN, you can configure RIP on the PE router to learn the routes of the CE router or to propagate the routes of the PE router to the CE router. RIP routes learned from neighbors configured at any [edit routing-instances] hierarchy level are added to the routing instance's inet table (*instance_name*.inet.0).

To configure RIP as the routing protocol between the PE and the CE router, include the rip statement at the [edit routing-instances *routing-instance-name* protocols] hierarchy level:

```
[edit routing-instances routing-instance-name protocols]
rip {
    group group-name {
        neighbor interface-name;
    }
}
```

To install routes learned from a RIP routing instance to multiple routing tables, configure the rib-group statement at the [edit protocols rip] hierarchy level or at the [edit routing-instances *routing-instance-name* protocols rip] hierarchy level:

```
[edit protocols rip]
rib-group inet group-name;
group group-name {
    neighbor interface-name;
}
```

To configure a routing table group, configure the rib-group statement at the [edit routing-options] hierarchy level.

To add a routing table to a routing table group, you need to configure the the import-rib statement at the [edit routing-options rib-groups *group-name*] hierarchy level. The first routing table name specified under the import-rib statement must be the name of the routing table you are configuring. See the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols* for more information about how to configure routing tables and routing table groups.

Configure the import-rib statement at the [edit routing-options rib-groups *group-name*] hierarchy level as follows:

```
[edit routing-options rib-groups group-name]
import-rib [group-name]
```

Configure Static Routes between the PE and CE Routers

To configure a static route between the PE and the CE routers, include the routing-options static statement at the [edit routing-instances *routing-instance-name* routing-options] hierarchy level:

```
[edit routing-instances routing-instance-name routing-options]
static {
    route destination-prefix {
        next-hop;
        static-options;
    }
}
```

For more information about configuring routing protocols and static routes, see the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

Limit the Routes Accepted from a CE Router

A route limit sets an upper limit for the number of prefixes installed into routing tables. You can use route limits to curtail the number of routes received from a CE router in a VPN. A route limit applies only to dynamic routing protocols, and is not applicable to static or interface routes.

To limit the number of routes accepted by a PE router from a CE router, include the maximum-routes statement at the [edit routing-instances *routing-instance-name* routing-options] hierarchy level:

```
[edit routing-instances routing-instance-name routing-options]
maximum-routes route-limit <log-only | threshold value>;
```

There are two modes for route limits: advisory (set with the log-only option) and mandatory. An advisory limit triggers only warnings. The log messages are rate-limited to once every 30 seconds. A mandatory limit, in addition to triggering a warning message, rejects any additional routes after the threshold is reached. The threshold value is a percentage of the route limit at which warning messages are logged.

Note

Setting a route limit might result in unpredictable dynamic routing protocol behavior.

Configure Multicast Over Layer 3 VPNs

You can configure a Layer 3 VPN to support multicast traffic using the Protocol-Independent Multicast (PIM) routing protocol. To support multicast, you need to configure PIM on routers within the VPN and within the service provider's network.

Each PE router configured to run multicast over Layer 3 VPNs must have a Tunnel PIC. A Tunnel PIC is also required on the provider routers that act as rendezvous points (RPs). Tunnel PICs are also needed on all the CE routers acting as designated routers (first-hop/last-hop routers) or as RPs, just as they are in non-VPN PIM environments.

Configure the master PIM instance at the [edit protocols pim] hierarchy level on the CE and PE routers. You also need to configure a PIM instance for the Layer 3 VPN at the [edit routing-instances *routing-instance-name* protocols pim] hierarchy level on the PE router. This creates a PIM instance for the indicated routing instance.

For information about how to configure PIM, see the *JUNOS Internet Software Configuration Guide: Multicast*.

The vpn-group-address statement is unique to a Layer 3 VPN PIM configuration. You use this statement to configure the group address for the VPN in the service provider's network. This address should be unique for each VPN. It ensures that multicast traffic is transmitted only to the specified VPN.

Configure the vpn-group-address statement at the [edit routing-instances *routing-instance-name* protocols pim] hierarchy level:

```
[edit routing-instances routing-instance-name protocols]
pim {
    vpn-group-address address;
}
```

The rest of the Layer 3 VPN configuration for multicast is conventional and is described in other sections of this manual. Most of the specific configuration tasks needed to activate multicast in a VPN environment involve PIM. For more information about how to configure PIM and multicast in JUNOS, including an example of how to configure multicast over Layer 3 VPNs, see the *JUNOS Internet Software Configuration Guide: Multicast*.

Configure a GRE Tunnel Interface for Layer 3 VPNs

JUNOS allows you to configure a GRE tunnel between the PE and CE routers for a Layer 3 VPN. The GRE tunnel can have one or more hops.

For more information about how to configure tunnel interfaces, see the *JUNOS Internet Software Configuration Guide: Interfaces and Class of Service.*

To configure a GRE tunnel between the PE and CE routers for Layer 3 VPN, complete the procedures in the following sections:

- Configure the GRE Tunnel Interface on the PE Router on page 92
- Configure the GRE Tunnel Interface on the CE Router on page 93

Configure the GRE Tunnel Interface on the PE Router

Configure the GRE tunnel interface on the PE router:

```
[edit]
interfaces {
    interface-name {
        unit 0 {
            tunnel {
                source address;
                destination address;
            }
            family inet {
                address address;
            }
            family mpls;
        }
    }
}
```

By default, the tunnel destination address is assumed to be in the default Internet routing table, inet.0. If the tunnel destination address is not in inet.0, you need to specify which routing table to search for the tunnel destination address by configuring the routing-instance statement. This is the case if the tunnel encapsulating interface is also configured under the routing instance.

Configure the GRE tunnel interface on the PE router and specify the name of the routing instance:

```
[edit]
interfaces {
    interface-name {
        unit 0 {
            tunnel {
                source address;
                destination address;
                routing-instance {
                    destination routing-instance-name;
                }
                family inet {
                    address address;
                }
                family mpls;
            }
        }
    }
}
```

To complete the GRE tunnel interface configuration, you need to configure the GRE interface at the [edit routing-instances *routing-instance-name*] hierarchy level under the appropriate routing-instance:

```
[edit]
routing-instances {
    routing-instance-name {
        interface interface-name;
    }
}
```

Configure the GRE Tunnel Interface on the CE Router

Configure the GRE tunnel interface on the CE router as follows:

```
[edit]
interfaces {
    interface-name {
        unit 0 {
            tunnel {
                source address;
                destination address;
            }
            family inet {
                address address;
            }
        }
    }
}
```

Configure an ES Tunnel Interface for Layer 3 VPNs

An ES tunnel interface allows you to configure an IPSec tunnel between the PE and CE routers of a Layer 3 VPN. The IPSec tunnel can include one or more hops.

To configure an ES tunnel interface between the PE and CE routers of a Layer 3 VPN, complete the procedures outlined in the following sections:

- Configure an ES Tunnel Interface on the PE Router on page 93
- Configure the ES Tunnel Interface on the CE Router on page 95

Configure an ES Tunnel Interface on the PE Router

Configure the ES tunnel interface on the PE router as follows:

```
[edit]
interfaces {
    interface-name {
        unit 0 {
            tunnel {
                source address;
                destination address;
            }
            family inet {
                address address;
                ipsec-sa security-association-name;
            }
            family mpls;
        }
    }
}
```

By default, the tunnel destination address is assumed to be in the default Internet routing table, inet.0. For IPSec tunnels using manual security association (SA), if the tunnel destination address is not in the default inet.0 routing table, you need to specify which routing table to search for the tunnel destination address by configuring the routing-instance statement. This is the case if the tunnel encapsulating interface is also configured under the routing instance.

```
[edit]
interfaces {
    interface-name {
        unit 0 {
            tunnel {
                source address;
                destination address;
                routing-instance {
                    destination routing-instance-name;
                }
                family inet {
                    address address;
                    ipsec-sa security-association-name;
                }
                family mpls;
            }
        }
    }
}
```

Note

For IPSec tunnels using dynamic security association (SA), the tunnel destination address must be in the default Internet routing table, inet.0.

You also need to configure the ES interface at the [edit routing-instances *routing-instance-name*] hierarchy level for the appropriate routing instance:

```
[edit]
routing-instances {
    routing-instance-name {
        interface interface-name;
    }
}
```

Configure the ES Tunnel Interface on the CE Router

Configure the ES tunnel interface on the CE router as follows:

```
[edit]
interfaces {
    interface-name {
        unit 0 {
            tunnel {
                source address;
                destination address;
            }
            family inet {
                address address;
                ipsec-sa security-association-name;
            }
        }
    }
}
```

For more information about how to configure tunnel interfaces, see the *JUNOS Internet Software Configuration Guide: Interfaces and Class of Service*.

For more information about how to configure IPSec interfaces, see the *JUNOS Internet Software Configuration Guide: Getting Started*.

Configure IPSec Between PE Routers Instead of MPLS

A conventional Layer 3 BGP/MPLS VPN requires the configuration of MPLS LSPs between the PE routers. When a PE router receives a packet from a CE router, it performs a lookup in a specific VRF table for the IP destination address and obtains a corresponding MPLS label stack. The label stack is used to forward the packet to the egress PE router, where the bottom label is removed and the packet is forwarded to the specified CE router.

You can provide Layer 3 BGP/MPLS VPN service without an MPLS backbone. Instead of configuring MPLS LSPs between the PE routers, you configure GRE and IPSec tunnels between the PE routers. The MPLS information for the VPN (the VPN label) is encapsulated within an IP header and an IPSec header. The source address of the IP header is the address of the ingress PE router. The destination address has the BGP next hop, the address of the egress PE router.

> **Note** The IPSec tunnel requires the use of an Encryption Services (ES) PIC. The GRE tunnel requires the use of a Tunnel PIC.

To configure IPSec between PE routers, complete the following:

1. Configure an IPSec tunnel between the PE routers. The source address is that of the ingress PE router, and the destination address is that of the egress PE router:

   ```
   [edit interfaces]
   es-interface-name {
       unit unit-number {
           tunnel {
               source source-address;
               destination destination-address;
           }
           family inet {
               ipsec-sa sa-esp-dynamic;
               address address;
           }
           family mpls;
       }
   }
   ```

2. Configure IPSec on the PE router. For information about how to configure IPSec, see the *JUNOS Internet Software Configuration Guide: Getting Started*.

3. Configure a GRE tunnel between the PE routers. Again, the source address is that of the ingress PE router, and the destination address is that of the egress PE router:

   ```
   [edit interfaces]
   gr-interface-name {
       unit unit-number {
           family inet {
               address address;
           }
           family mpls;
           tunnel {
               source source-address;
               destination destination-address;
           }
       }
   }
   ```

4. Configure BGP between the PE routers:

   ```
   [edit protocols]
   bgp {
       group pe {
           type internal;
           local-address local-address;
           family inet {
               unicast;
           }
           family inet-vpn {
               unicast;
           }
           peer-as as-number;
           neighbor address;
       }
   }
   ```

5. Configure the routing instance:

```
[edit]
routing-instances {
    routing-instance-name {
        instance-type vrf;
        interface interface-name;
        route-distinguisher address;
        vrf-import import-policy-name;
        vrf-export export-policy-name;
        protocols {
            bgp {
                group routing-instance-name {
                    type external;
                    peer-as as-number;
                    as-override;
                    neighbor address;
                }
            }
        }
    }
}
```

6. Configure the policy options:

```
[edit]
policy-options {
    policy-statement import-policy-name {
        term 1 {
            from {
                protocol bgp;
                community community-name;
            }
            then accept;
        }
        term 2 {
            then reject;
        }
    }
    policy-statement export-policy-name {
        term 1 {
            from protocol [ bgp direct ];
            then {
                community add community-name;
                accept;
            }
        }
        term 2 {
            then reject;
        }
    }
community community-name members target:target;
}
```

Chapter 8

Layer 3 VPN Configuration Troubleshooting Guidelines

This chapter discusses the following strategies and tools for troubleshooting Layer 3 virtual private network (VPN) configurations:

- Diagnose Common Problems on page 99
- Use the Ping and Traceroute Commands to Troubleshoot Layer 3 VPN Topologies on page 103
- Indirect Next-hop Address Space and Route Reflectors on page 110

Diagnose Common Problems

When problems arise in a Layer 3 VPN configuration, the best way to troubleshoot is to start at one end of the VPN (the local customer edge [CE] router) and follow the routes to the other end of the VPN (the remote CE router). The following troubleshooting steps should help you diagnose common problems:

1. If you configured a routing protocol between the local provider edge (PE) and CE routers, check that the peering and adjacency are fully operational. When you do this, be sure to specify the name of the routing instance. For example, to check OSPF adjacencies, enter the command show ospf neighbor instance *routing-instance-name* on the PE router.

   If the peering and adjacency are not fully operational, check the routing protocol configuration on the CE router and check the routing protocol configuration for the associated VPN routing instance on the PE router.

2. Check that the local CE and PE routers can ping each other.

   To check that the local CE router can ping the VPN interface on the local PE router, use a ping command in the following format, specifying the IP address or name of the PE router:

   ```
   ping (ip-address | host-name)
   ```

   To check that the local PE router can ping the CE router, use a ping command in the following format, specifying the IP address or name of the CE router, the name of the interface used for the VPN, and the source IP address (the local address) in outgoing ECHO_REQUEST packets:

   ```
   ping ip-address vpn-interface interface local echo-address
   ```

Often, the peering or adjacency between the local CE and local PE routers needs to come up before a ping command is successful. To check that a link is operational in a lab setting, remove the interface from the VRF by deleting the interface statement from the [edit routing-instance *routing-instance-name*] hierarchy level and recommitting the configuration. Doing this removes the interface from the VPN. Then try the ping command again. If the command is successful, configure the interface back into the VPN and check the routing protocol configuration on the local CE and PE routers again.

3. On the local PE router, check that the routes from the local CE router are in the VRF routing table (*routing-instance-name*.inet.0):

   show route table *routing-instance-name*.inet.0 [detail]

   The following example shows the routing table entries. Here, the loopback address of the CE router is 10.255.14.155/32 and the routing protocol between the PE and CE routers is BGP. The entry looks like any ordinary BGP announcement.

```
10.255.14.155/32 (1 entry, 1 announced)
        *BGP    Preference: 170/-101
                Nexthop: 192.168.197.141 via fe-1/0/0.0, selected
                State: <Active Ext>
                Peer AS:     1
                Age: 45:46
                Task: BGP_1.192.168.197.141+179
                Announcement bits (2): 0-BGP.0.0.0.0+179 1-KRT
                AS path: 1 I
                Localpref: 100
                Router ID: 10.255.14.155
```

   If the routes from the local CE router are not present in the VRF routing table, check that the CE router is advertising routes to the PE router. If static routing is used between the CE and PE routers, make sure the proper static routes are configured.

4. On a remote PE router, check that the routes from the local CE router are present in the bgp.l3vpn.0 routing table:

   show route table bgp.l3vpn.0 extensive

   The following example shows the routing table entries.

```
10.255.14.175:3:10.255.14.155/32 (1 entry, 0 announced)
        *BGP    Preference: 170/-101
                Route Distinguisher: 10.255.14.175:3
                Source: 10.255.14.175
                Nexthop: 192.168.192.1 via fe-1/1/2.0, selected
                label-switched-path vpn07-vpn05
                Push 100004, Push 100005(top)
                State: <Active Int Ext>
                Local AS:    69 Peer AS:    69
                Age: 15:27      Metric2: 338
                Task: BGP_69.10.255.14.175+179
                AS path: 1 I
                Communities: target:69:100
                BGP next hop: 10.255.14.175
                Localpref: 100
                Router ID: 10.255.14.175
                Secondary tables: VPN-A.inet.0
```

The output of the show route table bgp.l3vpn.0 extensive command contains the following information specific to the VPN:

- In the prefix name (the first line of the output), the route distinguisher is added to the route prefix of the local CE router. Because the route distinguisher is unique within the Internet, the concatenation of the route distinguisher and IP prefix provides unique VPN-IPv4 routing entries.

- The Route Distinguisher field lists the route distinguisher separately from the VPN-IPv4 address.

- The label-switched-path field shows the name of the LSP used to carry the VPN traffic.

- The Push field shows both labels being carried in the VPN-IPv4 packet. The first label is the inner label, which is the VPN label that was assigned by the PE router. The second label is the outer label, which is an RSVP label.

- The Communities field lists the target community.

- The Secondary tables field lists other routing tables on this router into which this route has been installed.

If routes from the local CE router are not present in the bgp.l3vpn.0 routing table on the remote PE router, do the following:

- Check the VRF import filter on the remote PE router, which is configured in the vrf-import statement. (On the local PE router, you check the VRF export filter, which is configured with the vrf-export statement.)

- Check that there is an operational LSP or an LDP path between the PE routers. To do this, check that the IBGP next-hop addresses are in the inet.3 table.

- Check that the IBGP session between the PE routers is established and configured properly.

- Check for “hidden” routes, which usually means that routes were not labeled properly. To do this, use the show route table bgp.l3vpn.0 hidden command.

- Check that the inner label matches the inner VPN label that is assigned by the local PE router. To do this, use the show route table mpls command.

  The following example shows the output of this command on the remote PE router. Here, the inner label is 100004.

  ```
  ...
  Push 100004, Push 10005 (top)
  ```

  The following example shows the output of this command on the local PE router, which shows that the inner label of 100004 matches the inner label on the remote PE router:

  ```
  ...
  100004             *[VPN/7] 06:56:25, metric 1
                   > to 192.168.197.141 via fe-1/0/0.0, Pop
  ```

5. On the remote PE router, check that the routes from the local CE router are present in the VRF table (*routing-instance-name*.inet.0):

   ```
   show route table routing-instance-name.inet.0 [detail]
   ```

   The following example shows the routing table entries.

   ```
   10.255.14.155/32 (1 entry, 1 announced)
           *BGP    Preference: 170/-101
                   Route Distinguisher: 10.255.14.175:3
                   Source: 10.255.14.175
                   Nexthop: 192.168.192.1 via fe-1/1/2.0, selected
                   label-switched-path vpn07-vpn05
                   Push 100004, Push 100005(top)
                   State: <Secondary Active Int Ext>
                   Local AS:    69 Peer AS:    69
                   Age: 1:16:22    Metric2: 338
                   Task: BGP_69.10.255.14.175+179
                   Announcement bits (2): 1-KRT 2-VPN-A-RIP
                   AS path: 1 I
                   Communities: target:69:100
                   BGP next hop: 10.255.14.175
                   Localpref: 100
                   Router ID: 10.255.14.175
                   Primary Routing Table bgp.l3vpn.0
   ```

   In this routing table, the route distinguisher is no longer prepended to the prefix. The last line, Primary Routing Table, lists the table from which this route was learned.

   If the routes are not present in this routing table, but were present in Step 4, the routes might have not passed the VRF import policy on the remote PE router.

   If a VPN-IPv4 route matches no vrf-import policy, the route does not show up in the bgp.l3vpn table at all and hence is not present in the VRF table. If this occurs, it might indicate that on the PE router, you have configured another vrf-import statement on another VPN (with a common target), and the routes show up in the bgp.l3vpn.0 table, but are imported into the wrong VPN.

6. On the remote CE router, check that the routes from the local CE router are present in the routing table (inet.0):

   ```
   show route
   ```

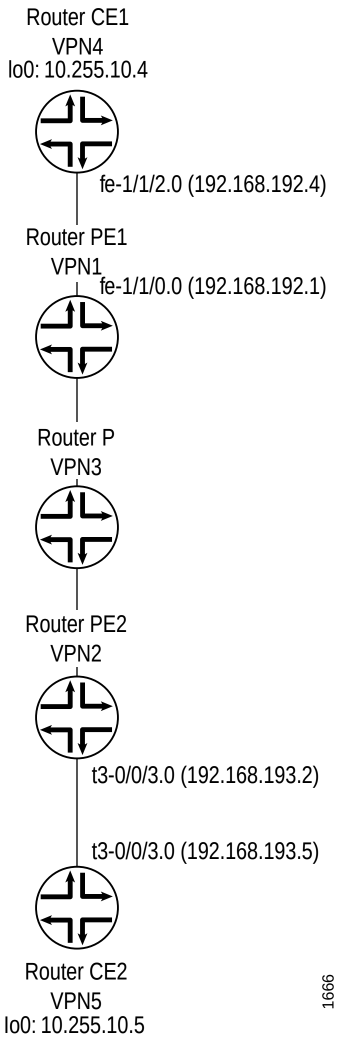
   If the routes are not present, check the routing protocol configuration between the remote PE and CE routers, and make sure that peers and adjacencies (or static routes) between the PE and CE routers are correct.

7. If, in Steps 1 through 6, you have determined that routes originated from the local CE router are correct, check the routes originated from the remote CE router by repeating Steps 1 through 6.

Use the Ping and Traceroute Commands to Troubleshoot Layer 3 VPN Topologies

This section provides examples of how to use the ping command to check the accessibility of various routers in a VPN topology, and how to use the traceroute command to check the path that packets travel between the VPN routers. The topology shown in Figure 15 illustrates these commands.

Figure 15: Layer 3 VPN Topology for Ping and Traceroute Command Examples


Router CE1
VPN4
lo0: 10.255.10.4
fe-1/1/2.0 (192.168.192.4)
Router PE1
VPN1
fe-1/1/0.0 (192.168.192.1)
Router P
VPN3
Router PE2
VPN2
t3-0/0/3.0 (192.168.193.2)
t3-0/0/3.0 (192.168.193.5)
Router CE2
VPN5
lo0: 10.255.10.5
1666

Ping One CE Router from the Other

You can ping one CE router from the other by specifying the other CE router's loopback address as the IP address in the ping command. This ping command succeeds if the loopback addresses have been announced by the CE routers to their directly connected PE routers. The success of these ping commands also means that Router CE1 can ping any network devices beyond Router CE2, and vice versa. See Figure 15 for the topology referenced in these examples.

Ping Router CE2 (VPN5) from Router CE1 (VPN4):

```
user@vpn4> ping 10.255.10.5 local 10.255.10.4 count 3
PING 10.255.10.5 (10.255.10.5): 56 data bytes
64 bytes from 10.255.10.5: icmp_seq=0 ttl=253 time=1.086 ms
64 bytes from 10.255.10.5: icmp_seq=1 ttl=253 time=0.998 ms
64 bytes from 10.255.10.5: icmp_seq=2 ttl=253 time=1.140 ms

--- 10.255.10.5 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.998/1.075/1.140/0.059 ms
```

To determine the path from Router CE1's loopback interface to Router CE2's loopback interface, use the following traceroute command:

```
user@vpn4> traceroute 10.255.10.5 source 10.255.10.4
traceroute to 10.255.10.5 (10.255.10.5) from 10.255.10.4, 30 hops max, 40 byte
packets
 1  vpn1-fe-110.isp-core.net (192.168.192.1)  0.680 ms  0.491 ms  0.456 ms
 2  vpn2-t3-001.isp-core.net (192.168.192.110)  0.857 ms  0.766 ms  0.754 ms
     MPLS Label=100005 CoS=0 TTL=1 S=1
 3  vpn5.isp-core.net (10.255.10.5)  0.825 ms  0.886 ms  0.732 ms
```

Ping Router CE1 (VPN4) from Router CE2 (VPN5):

```
user@vpn5> ping 10.255.10.4 local 10.255.10.5 count 3
PING 10.255.10.4 (10.255.10.4): 56 data bytes
64 bytes from 10.255.10.4: icmp_seq=0 ttl=253 time=1.042 ms
64 bytes from 10.255.10.4: icmp_seq=1 ttl=253 time=0.998 ms
64 bytes from 10.255.10.4: icmp_seq=2 ttl=253 time=0.954 ms

--- 10.255.10.4 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.954/0.998/1.042/0.036 ms
```

To determine the path from Router CE2 to Router CE1, use the following traceroute command:

```
user@vpn5> traceroute 10.255.10.4 source 10.255.10.5
traceroute to 10.255.10.4 (10.255.10.4) from 10.255.10.5, 30 hops max, 40 byte
packets
 1  vpn-08-t3-003.isp-core.net (192.168.193.2)  0.686 ms  0.519 ms  0.548 ms
 2  vpn1-so-100.isp-core.net (192.168.192.100)  0.918 ms  0.869 ms  0.859 ms
     MPLS Label=100021 CoS=0 TTL=1 S=1
 3  vpn4.isp-core.net (10.255.10.4)  0.878 ms  0.760 ms  0.739 ms
```

Ping the Remote PE and CE Routers from the Local CE Router

From the local CE router, you can ping the VPN interfaces on the remote PE and CE routers, which are point-to-point interfaces. See Figure 15 for the topology referenced in these examples.

Ping Router CE2 (VPN5) from Router CE1 (VPN4):

```
user@vpn4> ping 192.168.193.5 local 10.255.10.4 count 3
PING 192.168.193.5 (192.168.193.5): 56 data bytes
64 bytes from 192.168.193.5: icmp_seq=0 ttl=253 time=1.040 ms
64 bytes from 192.168.193.5: icmp_seq=1 ttl=253 time=0.891 ms
64 bytes from 192.168.193.5: icmp_seq=2 ttl=253 time=0.944 ms

--- 192.168.193.5 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.891/0.958/1.040/0.062 ms
```

To determine the path from Router CE1's loopback interface to Router CE2's directly connected interface, use the following traceroute command:

```
serpil@vpn4> traceroute 192.168.193.5 source 10.255.10.4
traceroute to 192.168.193.5 (192.168.193.5) from 10.255.10.4, 30 hops max, 40
byte packets
 1  vpn1-fe-110.isp-core.net (192.168.192.1)  0.669 ms  0.508 ms  0.457 ms
 2  vpn2-t3-001.isp-core.net (192.168.192.110)  0.851 ms  0.769 ms  0.750 ms
     MPLS Label=100000 CoS=0 TTL=1 S=1
 3  vpn5-t3-003.isp-core.net (192.168.193.5)  0.829 ms  0.838 ms  0.731 ms
```

Ping Router PE2 (VPN2) from Router CE1 (VPN4). In this case, packets that originate at Router CE1 go to Router PE2, then to Router CE2, and back to Router PE2 before Router PE2 can respond to ICMP requests. You can verify this using the traceroute command.

```
user@vpn4> ping 192.168.193.2 local 10.255.10.4 count 3
PING 192.168.193.2 (192.168.193.2): 56 data bytes
64 bytes from 192.168.193.2: icmp_seq=0 ttl=254 time=1.080 ms
64 bytes from 192.168.193.2: icmp_seq=1 ttl=254 time=0.967 ms
64 bytes from 192.168.193.2: icmp_seq=2 ttl=254 time=0.983 ms

--- 192.168.193.2 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.967/1.010/1.080/0.050 ms
```

To determine the path from Router CE1 to Router PE2, use the following traceroute command:

```
user@vpn4> traceroute 192.168.193.2 source 10.255.10.4
traceroute to 192.168.193.2 (192.168.193.2) from 10.255.10.4, 30 hops max, 40
byte packets
 1  vpn1-fe-110.isp-core.net (192.168.192.1)  0.690 ms  0.490 ms  0.458 ms
 2  vpn2-t3-003.isp-core.net (192.168.193.2)  0.846 ms  0.768 ms  0.749 ms
     MPLS Label=100000 CoS=0 TTL=1 S=1
 3  vpn5-t3-003.isp-core.net (192.168.193.5)  0.643 ms  0.703 ms  0.600 ms
 4  vpn-08-t3-003.isp-core.net (192.168.193.2)  0.810 ms  0.739 ms  0.729 ms
```

You cannot ping one CE router from the other if the VPN interface is a multiaccess interface, such as the fe-1/1/2.0 interface on Router CE1. To ping Router CE1 from Router CE2, you must configure a static route on Router PE1 to the VPN interface of Router CE1 that has a next hop pointing to Router CE1 (at the [edit routing-instance *routing-instance-name*] hierarchy level) and this route must be announced from Router PE1 to Router PE2. The following configuration portions illustrate this configuration:

```
[edit]
routing-instances {
    direct-multipoint {
        instance-type vrf;
        interface fe-1/1/0.0;
        route-distinguisher 69:1;
        vrf-import direct-import;
        vrf-export direct-export;
        routing-options {
            static {
                route 192.168.192.4/32 next-hop 192.168.192.4;
            }
        }
    protocols {
        bgp {
            group to-vpn4 {
                peer-as 1;
                neighbor 192.168.192.4;
            }
        }
    }
}
policy-options {
    policy-statement direct-export {
            term a {
                from protocol bgp;
                then {
                    community add direct-comm;
                    accept;
                }
            }
            term b {
                from {
                    protocol static;
                    route-filter 192.168.192.4/32 exact;
                }
                then {
                    community add direct-comm;
                    accept;
                }
            }
            term d {
                then reject;
            }
        }
    }
}
```

Now you can ping Router CE1 from Router CE2:

```
user@vpn5> ping 192.168.192.4 local 10.255.10.5 count 3
PING 192.168.192.4 (192.168.192.4): 56 data bytes
64 bytes from 192.168.192.4: icmp_seq=0 ttl=253 time=1.092 ms
64 bytes from 192.168.192.4: icmp_seq=1 ttl=253 time=1.019 ms
64 bytes from 192.168.192.4: icmp_seq=2 ttl=253 time=1.031 ms

--- 192.168.192.4 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 1.019/1.047/1.092/0.032 ms
```

To determine the path between these two interfaces, use the following traceroute command:

```
user@vpn5> traceroute 192.168.192.4 source 10.255.10.5
traceroute to 192.168.192.4 (192.168.192.4) from 10.255.10.5, 30 hops max, 40
byte packets
 1  vpn-08-t3003.isp-core.net (192.168.193.2)  0.678 ms  0.549 ms  0.494 ms
 2  vpn1-so-100.isp-core.net (192.168.192.100)  0.873 ms  0.847 ms  0.844 ms
     MPLS Label=100021 CoS=0 TTL=1 S=1
 3  vpn4-fe-112.isp-core.net (192.168.192.4)  0.825 ms  0.743 ms  0.764 ms
```

Ping the Directly Connected PE and CE Routers from Each Other

From the loopback interfaces on the CE routers, you can ping the VPN interface on the directly connected PE router. See Figure 15 for the topology referenced in these examples.

From the loopback interface on Router CE1 (VPN4), ping the VPN interface, fe-1/1/0.0, on Router PE1:

```
user@vpn4> ping 192.168.192.1 local 10.255.10.4 count 3
PING 192.168.192.1 (192.168.192.1): 56 data bytes
64 bytes from 192.168.192.1: icmp_seq=0 ttl=255 time=0.885 ms
64 bytes from 192.168.192.1: icmp_seq=1 ttl=255 time=0.757 ms
64 bytes from 192.168.192.1: icmp_seq=2 ttl=255 time=0.734 ms

--- 192.168.192.1 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.734/0.792/0.885/0.066 ms
```

To determine the path from the loopback interface on Router CE1 to the VPN interfaces on Router PE1, use the following traceroute command:

```
user@vpn4> traceroute 192.168.192.1 source 10.255.10.4
traceroute to 192.168.192.1 (192.168.192.1) from 10.255.10.4, 30 hops max, 40
byte packets
 1  vpn1-fe-110.isp-core.net (192.168.192.1)  0.828 ms  0.657 ms  1.972 ms
```

From the loopback interface on Router CE2 (VPN5), ping the VPN interface, t3-0/0/3.0, on Router PE2:

```
user@vpn5> ping 192.168.193.2 local 10.255.10.5 count 3
PING 192.168.193.2 (192.168.193.2): 56 data bytes
64 bytes from 192.168.193.2: icmp_seq=0 ttl=255 time=0.998 ms
64 bytes from 192.168.193.2: icmp_seq=1 ttl=255 time=0.834 ms
64 bytes from 192.168.193.2: icmp_seq=2 ttl=255 time=0.819 ms

--- 192.168.193.2 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.819/0.884/0.998/0.081 ms
```

To determine the path from the loopback interface on Router CE2 to the VPN interfaces on Router PE2, use the following traceroute command:

```
serpil@vpn5> traceroute 192.168.193.2 source 10.255.10.5
traceroute to 192.168.193.2 (192.168.193.2) from 10.255.10.5, 30 hops max, 40
byte packets
 1  vpn-08-t3003.isp-core.net (192.168.193.2)  0.852 ms  0.670 ms  0.656 ms
```

From the VPN interface on the PE router, you can ping the VPN or loopback interface on the directly connected CE router.

From the VPN interface on Router PE1 (VPN1), ping the VPN interface on Router CE1, fe-1/1/0.0:

```
user@vpn1> ping 192.168.192.4 vpn-interface fe-1/1/0.0 local 192.168.192.1 count
3
PING 192.168.192.4 (192.168.192.4): 56 data bytes
64 bytes from 192.168.192.4: icmp_seq=0 ttl=255 time=0.866 ms
64 bytes from 192.168.192.4: icmp_seq=1 ttl=255 time=0.728 ms
64 bytes from 192.168.192.4: icmp_seq=2 ttl=255 time=0.753 ms

--- 192.168.192.4 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.728/0.782/0.866/0.060 ms
```

From the VPN interface on Router PE1 (VPN1), ping the loopback interface on Router CE1, 10.255.10.4:

```
user@vpn1> ping 10.255.10.4 vpn-interface fe-1/1/0.0 local 192.168.192.1 count 3
PING 10.255.10.4 (10.255.10.4): 56 data bytes
64 bytes from 10.255.10.4: icmp_seq=0 ttl=255 time=0.838 ms
64 bytes from 10.255.10.4: icmp_seq=1 ttl=255 time=0.760 ms
64 bytes from 10.255.10.4: icmp_seq=2 ttl=255 time=0.771 ms

--- 10.255.10.4 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.760/0.790/0.838/0.034 ms
```

To determine the path from the VPN interface on Router PE1 to the VPN and loopback interfaces on Router CE1, respectively, use the following traceroute commands:

```
user@vpn1> traceroute 10.255.10.4 vpn-interface fe-1/1/0.0 source 192.168.192.1
traceroute to 10.255.10.4 (10.255.10.4) from 192.168.192.1, 30 hops max, 40 byte
packets
 1  vpn4.isp-core.net (10.255.10.4)  0.842 ms  0.659 ms  0.621 ms

user@vpn1> traceroute 192.168.192.4 vpn-interface fe-1/1/0.0 source
192.168.192.1
traceroute to 192.168.192.4 (192.168.192.4) from 192.168.192.1, 30 hops max, 40
byte packets
 1  vpn4-fe-112.isp-core.net (192.168.192.4)  0.810 ms  0.662 ms  0.640 ms
```

From the VPN interface on Router PE2 (VPN2), ping the VPN interface on Router CE2, t3-0/0/3.0:

```
user@vpn2> ping 192.168.193.5 vpn-interface t3-0/0/3.0 local 192.168.193.2
count 3
PING 192.168.193.5 (192.168.193.5): 56 data bytes
64 bytes from 192.168.193.5: icmp_seq=0 ttl=255 time=0.852 ms
64 bytes from 192.168.193.5: icmp_seq=1 ttl=255 time=0.909 ms
64 bytes from 192.168.193.5: icmp_seq=2 ttl=255 time=0.793 ms

--- 192.168.193.5 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.793/0.851/0.909/0.047 ms
```

From the VPN interface on Router PE2 (VPN2), ping the loopback interface on Router CE2, 10.255.10.5:

```
user@vpn2> ping 10.255.10.5 vpn-interface t3-0/0/3.0 local 192.168.193.2 count 3
PING 10.255.10.5 (10.255.10.5): 56 data bytes
64 bytes from 10.255.10.5: icmp_seq=0 ttl=255 time=0.914 ms
64 bytes from 10.255.10.5: icmp_seq=1 ttl=255 time=0.888 ms
64 bytes from 10.255.10.5: icmp_seq=2 ttl=255 time=1.066 ms

--- 10.255.10.5 ping statistics ---
3 packets transmitted, 3 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.888/0.956/1.066/0.079 ms
```

To determine the path from the VPN interface on Router PE2 to the VPN and loopback interfaces on Router CE2, respectively, use the following traceroute commands:

```
user@vpn2> traceroute 10.255.10.5 vpn-interface t3-0/0/3.0 source 192.168.193.2
traceroute to 10.255.10.5 (10.255.10.5) from 192.168.193.2, 30 hops max, 40 byte
packets
 1  vpn5.isp-core.net (10.255.10.5)  1.009 ms  0.677 ms  0.633 ms

user@vpn2> traceroute 192.168.193.5 vpn-interface t3-0/0/3.0 source
192.168.193.2
traceroute to 192.168.193.5 (192.168.193.5) from 192.168.193.2, 30 hops max, 40
byte packets
 1  vpn5-t3-003.isp-core.net (192.168.193.5)  0.974 ms  0.665 ms  0.619 ms
```

Ping a Remote CE Router from a PE Router

If you attempt to ping a remote CE router from a PE router, Internet Control Message Protocol (ICMP) echo requests are sent from the PE router, with the PE router’s VPN interface as the source. Other PE routers have a route back to that address with a VPN label. When the echo replies return, they include a label. The PE router pops the VPN label and sends the packet from the VPN interface to the local CE router. The local CE router sends it back to the PE router, its actual destination.

When a Juniper Networks router receives a labeled packet, the label is popped (depending on the label operation specified), and the packet is forwarded to an interface, even if the packet is destined for that particular PE router. Labeled packets are not analyzed further for the IP information under the label.

If there is a problem with the connection to the local CE router, packets are sent out but do not return to the PE router, and the ping fails. So if the connection between your PE router and local CE router is down, sending a ping to the remote CE router fails even though the connection to the remote CE router might be functional.

Disable Normal TTL Decrementing for Layer 3 VPNs

For information on how to disable normal TTL decrementing for Layer 3 VPNs, see “Disable Normal TTL Decrementing for VPNs” on page 22.

Indirect Next-hop Address Space and Route Reflectors

If you attempt to allocate indirect next-hop indexes for all the active routes in the routing table, the indirect next-hop address space can be exhausted. This occurs most frequently in topologies in which a Juniper Networks router acts as a VPN route reflector and a BGP peer with other vendors’ routers. The other routers advertise unique label stacks per prefix, instead of sharing common label stacks across many prefixes.

You can configure a forwarding table export policy to prevent routes from being installed in the forwarding table, even when those routes are active in the routing table. With this change, the routes that are omitted from the forwarding table do not have additional indirect next-hop indexes allocated to them.

The following configuration avoids indirect next-hop address space exhaustion, but does not allow the router to forward traffic for the BGP learned prefixes:

```
routing-options {
    forwarding-table {
        export kern;
    }
}
policy-options {
    policy-statement kern {
        from protocol bgp;
        then reject;
    }
}
```

Chapter 9
Layer 3 VPN Configuration Examples

This chapter provides the following examples of Layer 3 virtual private network (VPN) configurations:

- Configure a Simple Full-Mesh VPN Topology on page 112
- Configure a Full-Mesh VPN Topology with Route Reflectors on page 126
- Configure a Hub-and-Spoke VPN Topology on page 126
- Configure an LDP-over-RSVP VPN Topology on page 142
- Configure an Application-Based Layer 3 VPN Topology on page 156
- Configure an OSPF Domain ID for a Layer 3 VPN on page 161
- Configure Overlapping VPNs Using Routing Table Groups on page 168
- Configuring Overlapping VPNs Using auto-export on page 180
- Configure a GRE Tunnel Interface between PE Routers on page 183
- Configure a GRE Tunnel Interface between a PE and CE Router on page 190
- Configure an ES Tunnel Interface between a PE and CE Router on page 194

Note

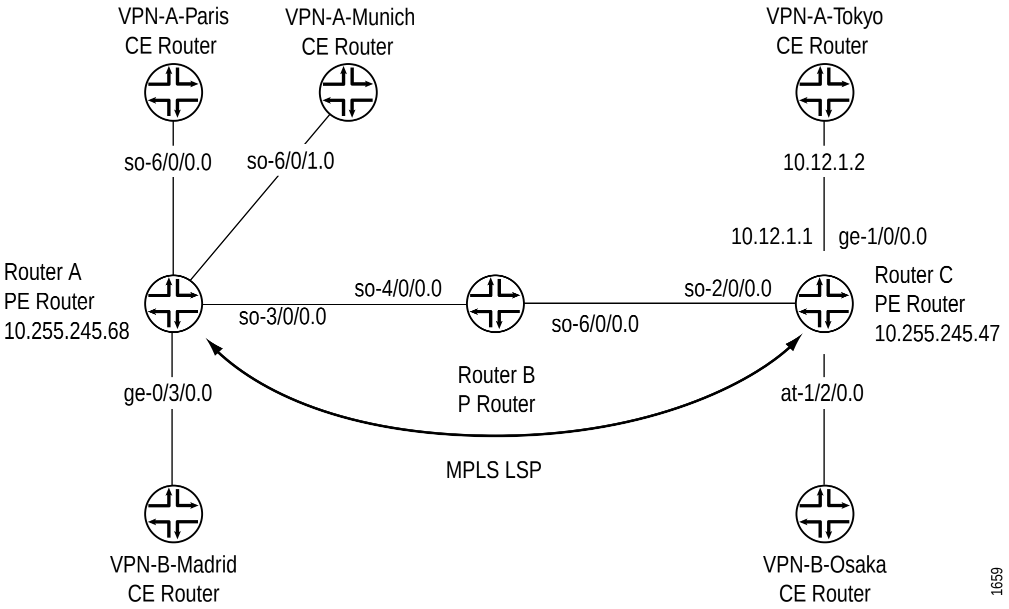
The examples in this chapter show only the portions of the configuration that establish VPN functionality. You must also configure other router functionality, including all router interfaces, for a router configuration to work properly.

Configure a Simple Full-Mesh VPN Topology

This example shows how to set up a simple full-mesh service provider VPN configuration, which consists of the following components (see Figure 16):

- Two separate VPNs (VPN-A and VPN-B)
- Two provider edge (PE) routers, both of which service VPN-A and VPN-B
- Resource Reservation Protocol (RSVP) as the signaling protocol
- One RSVP label-switched path (LSP) that tunnels between the two PE routers through one provider (P) router

Figure 16: Example of a Simple VPN Topology



In this configuration, route distribution in VPN A from the router VPN-A-Paris to the router VPN-A-Tokyo occurs as follows:

1. The customer edge (CE) router VPN-A-Paris announces routes to the PE router Router A.
2. Router A installs the received announced routes into its VPN Routing and Forwarding (VRF) table, VPN-A.inet.0.
3. Router A creates an MPLS label for the interface between it and the router VPN-A-Paris.
4. Router A checks its VRF export policy.
5. Router A converts the IPv4 routes from VPN-A-Paris into VPN IPv4 format using its route distinguisher and announces these routes to PE Router C over the IBGP between the two PE routers.

6. Router C checks its VRF import policy and installs all routes that match the policy into its bgp.l3vpn.0 routing table. (Any routes that do not match are discarded.)

7. Router C checks its VRF import policy and installs all routes that match into its VPN-A.inet.0 routing table. The routes are installed in IPv4 format.

8. Router C announces its routes to the CE router VPN-A-Tokyo, which installs them into its master routing table. (For routers running JUNOS software, the master routing table is inet.0.)

9. Router C uses the LSP between it and Router A to route all packets from router VPN-A-Tokyo that are destined for the router VPN-A-Paris.

The following sections explain how to configure the VPN functionality on the PE and provider routers. The CE routers are not aware of the VPN, so you configure them normally.

- Enable an IGP on the PE and Provider Routers on page 113
- Enable RSVP and MPLS on the Provider Router on page 114
- Configure the MPLS LSP Tunnel between the PE Routers on page 114
- Configure IBGP on the PE Routers on page 115
- Configure Routing Instances for VPNs on the PE Routers on page 116
- Configure VPN Policy on the PE Routers on page 118

The final section in this example, “Simple VPN Configuration Summarized by Router” on page 121, consolidates the statements needed to configure VPN functionality on each of the service provider routers shown in Figure 16.

Note

In this example, a private AS number is used for the route distinguisher and the route target. This number is used for illustration only. When you are configuring VPNs, you should use an assigned AS number.

Enable an IGP on the PE and Provider Routers

To allow the PE and provider routers to exchange routing information among themselves, you must configure an IGP on all these routers or you must configure static routes. You configure the IGP on the master instance of the routing protocol process (rpd) (that is, at the [edit protocols] hierarchy level), not within the VPN routing instance (that is, not at the [edit routing-instances] hierarchy level).

You configure the IGP in the standard way. This configuration example does not include this portion of the configuration.

Enable RSVP and MPLS on the Provider Router

On the provider router, Router B, you must configure RSVP and MPLS because this router exists on the MPLS LSP path between the two PE routers, Router A and Router C:

```
[edit]
protocols {
    rsvp {
        interface so-4/0/0.0;
        interface so-6/0/0.0;
    }
    mpls {
        interface so-4/0/0.0;
        interface so-6/0/0.0;
    }
}
```

Configure the MPLS LSP Tunnel between the PE Routers

In this configuration example, RSVP is used for VPN signaling. Therefore, in addition to configuring RSVP, you must enable traffic engineering support in an IGP and you must create an MPLS LSP to tunnel the VPN traffic.

On PE Router A, enable RSVP and configure one end of the MPLS LSP tunnel. In this example, traffic engineering support is enabled for OSPF. When configuring the MPLS LSP, include interface statements for all interfaces participating in MPLS, including the interfaces to the PE and CE routers. The statements for the interfaces between the PE and CE routers are needed so that the PE router can create an MPLS label for the private interface. In this example, the first interface statement configures MPLS on the interface connected to the LSP, and the remaining three configure MPLS on the interfaces that connect the PE router to the CE routers.

```
[edit]
protocols {
    rsvp {
        interface so-3/0/0.0;
    }
    mpls {
        label-switched-path RouterA-to-RouterC {
            to 10.255.245.47;
        }
        interface so-3/0/0.0;
        interface so-6/0/0.0;
        interface so-6/0/1.0;
        interface ge-0/3/0.0;
    }
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-3/0/0.0;
        }
    }
}
```

On PE Router C, enable RSVP and configure the other end of the MPLS LSP tunnel. Again, traffic engineering support is enabled for OSPF, and you configure MPLS on the interfaces to the LSP and the CE routers.

```
[edit]
protocols {
    rsvp {
        interface so-2/0/0.0;
    }
    mpls {
        label-switched-path RouterC-to-RouterA {
            to 10.255.245.68;
        }
        interface so-2/0/0.0;
        interface ge-1/0/0.0;
        interface at-1/2/0.0;
    }
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-2/0/0.0;
        }
    }
}
```

Configure IBGP on the PE Routers

On the PE routers, configure an IBGP session with the following properties:

- VPN family—To indicate that the IBGP session is for the VPN, include the family inet-vpn statement.
- Loopback address—Include the local-address statement, specifying the local PE router’s loopback address. The IBGP session for VPNs runs through the loopback address. Note that you must also configure the lo0 interface at the [edit interfaces] hierarchy level. The example does not include this part of the router’s configuration.
- Neighbor address—Include the neighbor statement, specifying the IP address of the neighboring PE router, which is its loopback (lo0) address.

On PE Router A, configure IBGP as follows:

```
[edit]
protocols {
    bgp {
        group PE-RouterA-to-PE-RouterC {
            type internal;
            local-address 10.255.245.68;
            family inet-vpn {
                unicast:
            }
            neighbor 10.255.245.47;
        }
    }
}
```

On PE Router C, configure IBGP as follows:

```
[edit]
protocols {
    bgp {
        group PE-RouterC-to-PE-RouterA {
            type internal;
            local-address 10.255.245.47;
            family inet-vpn {
                unicast:
            }
            neighbor 10.255.245.68;
        }
    }
}
```

Configure Routing Instances for VPNs on the PE Routers

Both PE routers service VPN-A and VPN-B, so you must configure two routing instances on each router, one for each VPN. For each VPN, you must define the following in the routing instance:

- Route distinguisher, which must be unique for each routing instance on the PE router. It is used to distinguish the addresses in one VPN from those in another VPN.
- Instance type of vrf, which creates the VRF table on the PE router.
- Interfaces connected to the CE routers.
- VRF import and export policies, which must be the same on each PE router that services the same VPN. Unless an import policy contains only a then reject statement, it must include reference to a community. Otherwise, when you try to commit the configuration, the commit fails.

> **Note**
>
> In this example, a private AS number is used for the route distinguisher. This number is used for illustration only. When you are configuring VPNs, you should use an assigned AS number.

- Routing between the PE and CE routers, which is required for the PE router to distribute VPN-related routes to and from connected CE routers. You can configure a routing protocol—BGP, OSPF, or RIP—or you can configure static routing.

On PE Router A, configure the following routing instance for VPN-A. In this example, Router A uses static routes to distribute routes to and from the two CE routers to which it is connected.

```
[edit]
routing-instance {
    VPN-A-Paris-Munich {
        instance-type vrf;
        interface so-6/0/0.0;
        interface so-6/0/1.0;
        route-distinguisher 65535:0;
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
        routing-options {
            static {
                route 172.16.0.0/16 next-hop so-0/0/0.0;
                route 172.17.0.0/16 next-hop so-6/0/1.0;
            }
        }
    }
}
```

On PE Router C, configure the following routing instance for VPN-A. In this example, Router C uses BGP to distribute routes to and from the CE router to which it is connected.

```
[edit]
routing-instance {
    VPN-A-Tokyo {
        instance-type vrf;
        interface ge-1/0/0.0;
        route-distinguisher 65535:1;
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
        protocols {
            bgp {
                group VPN-A-Site2 {
                    peer-as 1;
                    neighbor 10.12.1.2;
                }
            }
        }
    }
}
```

On PE Router A, configure the following routing instance for VPN-B. In this example, Router A uses OSPF to distribute routes to and from the CE router to which it is connected.

```
[edit]
routing-instance {
    VPN-B-Madrid {
        instance-type vrf;
        interface ge-0/3/0.0;
        route-distinguisher 65535:2;
        vrf-import VPN-B-import;
        vrf-export VPN-B-export;
        protocols {
            ospf {
                area 0.0.0.0 {
                    interface ge-0/3/0;
                }
            }
        }
    }
}
```

On PE Router C, configure the following routing instance for VPN-B. In this example, Router C uses RIP to distribute routes to and from the CE router to which it is connected.

```
[edit]
routing-instance {
    VPN-B-Osaka {
        instance-type vrf;
        interface at-1/2/0.0;
        route-distinguisher 65535:3;
        vrf-import VPN-B-import;
        vrf-export VPN-B-export;
        protocols {
            rip {
                group PE-C-to-VPN-B {
                    neighbor at-1/2/0;
                }
            }
        }
    }
}
```

Configure VPN Policy on the PE Routers

You must configure VPN import and export policies on each of the PE routers so that they install the appropriate routes in their VRF tables, which they use to forward packets within a VPN. For VPN-A, the VRF table is VPN-A.inet.0, and for VPN-B it is VPN-B.inet.0.

In the VPN policy, you also configure VPN target communities.

> **Note** In this example, a private AS number is used for the route target. This number is used for illustration only. When you are configuring VPNs, you should use an assigned AS number.

On PE Router A, configure the following VPN import and export policies.

> **Note**
>
> The policy qualifiers shown in this example are only those needed for the VPN to function. You can configure additional qualifiers, as needed, to any policies that you configure.

```
[edit]
policy-options {
    policy-statement VPN-A-import {
        term a {
            from {
                protocol bgp;
                community VPN-A;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-A-export {
        term a {
            from protocol static;
            then {
                community add VPN-A;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-B-import {
        term a {
            from {
                protocol bgp;
                community VPN-B;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-B-export {
        term a {
            from protocol ospf;
            then {
                community add VPN-B;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community VPN-A members target:65535:0;
    community VPN-B members target:65535:2;
}
```

On PE Router C, configure the following VPN import and export policies:

```
[edit]
policy-options {
    policy-statement VPN-A-import {
        term a {
            from {
                protocol bgp;
                community VPN-A;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-A-export {
        term a {
            from protocol bgp;
            then {
                community add VPN-A;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-B-import {
        term a {
            from {
                protocol bgp;
                community VPN-B;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-B-export {
        term a {
            from protocol rip;
            then {
                community add VPN-B;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community VPN-A members target:65535:1;
    community VPN-B members target:65535:3;
}
```

To apply the VPN policies on the routers, include the vrf-export and vrf-import statements when you configure the routing instance. For both VPNs, the VRF import and export policies handle the route distribution across the IBGP session running between the PE routers.

To apply the VPN policies on PE Router A, include the following statements:

```
[edit]
routing-instance {
    VPN-A-Paris-Munich {
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
    }
    VPN-B-Madrid {
        vrf-import VPN-B-import;
        vrf-export VPN-B-export;
    }
}
```

To apply the VPN policies on PE Router C, include the following statements:

```
[edit]
routing-instance {
    VPN-A-Tokyo {
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
    }
    VPN-B-Osaka {
        vrf-import VPN-B-import;
        vrf-export VPN-B-export;
    }
}
```

Simple VPN Configuration Summarized by Router

Router A (PE Router)

Routing Instance for VPN-A

```
routing-instance {
    VPN-A-Paris-Munich {
        instance-type vrf;
        interface so-6/0/0.0;
        interface so-6/0/1.0;
        route-distinguisher 65535:0;
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
```

Instance Routing Protocol

```
        routing-options {
            static {
                route 172.16.0.0/16 next-hop so-6/0/0.0;
                route 172.17.0.0/16 next-hop so-6/0/1.0;
            }
        }
    }
}
```

Routing Instance for VPN-B

```
routing-instance {
    VPN-B-Madrid {
        instance-type vrf;
        interface ge-0/3/0.0;
        route-distinguisher 65535:2;
        vrf-import VPN-B-import;
        vrf-export VPN-B-export;
```

Instance Routing Protocol

```
        protocols {
            ospf {
                area 0.0.0.0 {
                    interface ge-0/3/0;
                }
            }
        }
    }
}
```

Master Protocol Instance

```
protocols {
```

Enable RSVP

```
    rsvp {
        interface so-3/0/0.0;
    }
```

Configure an MPLS LSP

```
    mpls {
        label-switched-path RouterA-to-RouterC {
            to 10.255.245.47;
        }
        interface so-3/0/0.0;
        interface so-6/0/0.0;
        interface so-6/0/1.0;
        interface ge-0/3/0.0;
    }
```

Configure IBGP

```
    bgp {
        group PE-RouterA-to-PE-RouterC {
            type internal;
            local-address 10.255.245.68;
            family inet-vpn {
                unicast:
            }
            neighbor 10.255.245.47;
        }
    }
```

Configure OSPF for Traffic Engineering Support

```
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-3/0/0.0;
        }
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement VPN-A-import {
        term a {
            from {
                protocol bgp;
                community VPN-A;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-A-export {
        term a {
            from protocol static;
            then {
                community add VPN-A;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-B-import {
        term a {
            from {
                protocol bgp;
                community VPN-B;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-B-export {
        term a {
            from protocol ospf;
            then {
                community add VPN-B;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community VPN-A members target:65535:0;
    community VPN-B members target:65535:2;
}
```

Router B (Provider Router)

Master Protocol Instance

```
protocols {
```

Enable RSVP

```
    rsvp {
        interface so-4/0/0.0;
        interface so-6/0/0.0;
    }
```

Enable MPLS

```
    mpls {
        interface so-4/0/0.0;
        interface so-6/0/0.0;
    }
}
```

Router C (PE Router)

Routing Instance for VPN-A

```
routing-instance {
    VPN-A-Tokyo {
        instance-type vrf;
        interface ge-1/0/0.0;
        route-distinguisher 65535:1;
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
```

Instance Routing Protocol

```
        protocols {
            bgp {
                group VPN-A-Site2 {
                    peer-as 1;
                    neighbor 10.12.1.2;
                }
            }
        }
    }
```

Routing Instance for VPN-B

```
    VPN-B-Osaka {
        instance-type vrf;
        interface at-1/2/0.0;
        route-distinguisher 65535:3;
        vrf-import VPN-B-import;
        vrf-export VPN-B-export;
```

Instance Routing Protocol

```
        protocols {
            rip {
                group PE-C-to-VPN-B {
                    neighbor at-1/2/0;
                }
            }
        }
    }
}
```

Master Protocol Instance

```
protocols {
```

Enable RSVP

```
    rsvp {
        interface so-2/0/0.0;
    }
```

Configure an MPLS LSP

```
    mpls {
        label-switched-path RouterC-to-RouterA {
            to 10.255.245.68;
        }
        interface so-2/0/0.0;
        interface ge-1/0/0.0;
        interface at-1/2/0.0;
    }
```

Configure IBGP

```
    bgp {
        group PE-RouterC-to-PE-RouterA {
            type internal;
            local-address 10.255.245.47;
            family inet-vpn {
                unicast:
            }
            neighbor 10.255.245.68;
        }
    }
```

Configure OSPF for Traffic Engineering Support

```
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-2/0/0.0;
        }
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement VPN-A-import {
        term a {
            from {
                protocol bgp;
                community VPN-A;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-A-export {
        term a {
            from protocol bgp;
            then {
                community add VPN-A;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-B-import {
        term a {
            from {
                protocol bgp;
                community VPN-B;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-B-export {
        term a {
            from protocol rip;
            then {
                community add VPN-B;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community VPN-A members target:65535:1;
    community VPN-B members target:65535:3;
}
```

Configure a Full-Mesh VPN Topology with Route Reflectors

This example is a variation of the full-mesh VPN topology example (described in “Configure a Simple Full-Mesh VPN Topology” on page 112) in which one of the PE routers is a BGP route reflector. In this variation, Router C in Figure 16 on page 112 is a route reflector. The only change to its configuration is that you need to include the cluster statement when configuring the BGP group:

```
[edit protocols]
bgp {
    group PE-RouterC-to-PE-RouterA {
        type internal;
        local-address 10.255.245.47;
        family inet-vpn {
            unicast:
        }
        neighbor 10.255.245.68;
        cluster 4.3.2.1;
    }
}
```

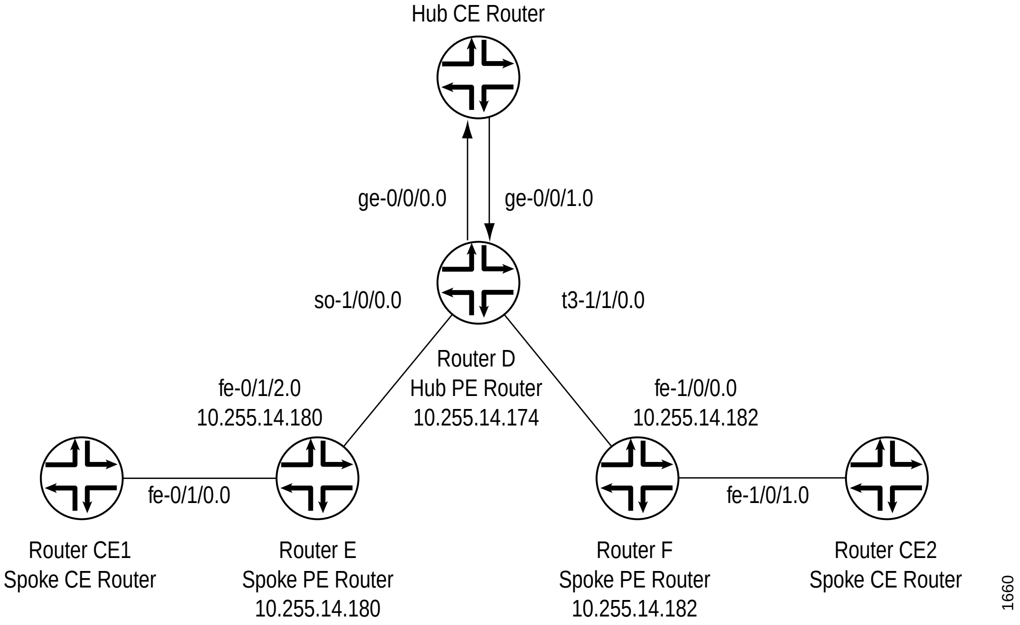
For the complete configuration example of Router C, see “Router C (PE Router)” on page 124.

Configure a Hub-and-Spoke VPN Topology

This example shows how to set up a hub-and-spoke VPN configuration, which consists of the following components (see Figure 17):

- One hub PE router (Router D).
- One hub CE router connected to the hub PE router. For a hub-and-spoke VPN topology to function properly, there must be two interfaces connecting the hub PE router to the hub CE router, and each interface must have its own VRF table on the PE router:
    - One interface (here, interface ge-0/0/0.0) is used to announce spoke routes to the hub CE router. The VRF table associated with this interface contains the routes being announced by the spoke PE routers to the hub CE router.
    - The second interface (here, interface ge-0/0/1.0) is used to receive route announcements from the hub CE that are destined for the hub and spoke routers. The VRF table associated with this interface contains the routes announced by the hub CE router to the spoke PE routers.
- Two spoke PE routers (Router E and Router F).
- Two spoke CE routers (CE1 and CE2), one connected to each spoke PE router.
- LDP as the signaling protocol.

Figure 17: Example of a Hub-and-Spoke VPN Topology

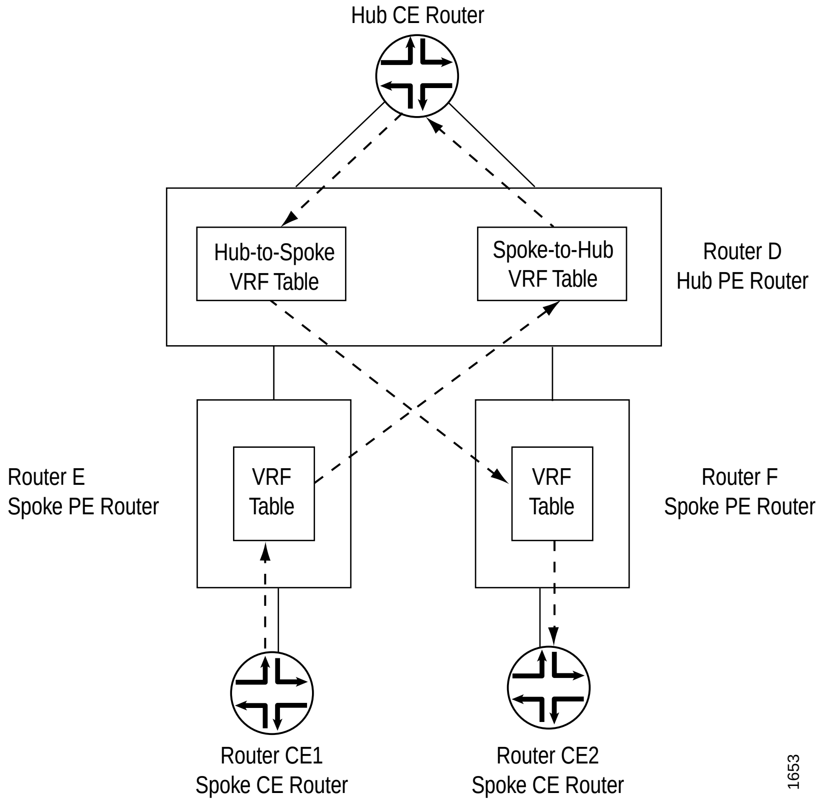


In this configuration, route distribution from spoke CE Router CE1 occurs as follows:

1. Spoke Router CE1 announces its routes to spoke PE Router E.
2. Router E installs the routes from CE1 into its VRF table.
3. After checking its VRF export policy, Router E adds the spoke target community to the routes from Router CE1 that passed the policy and announces them to the hub PE router, Router D.
4. Router D checks the VRF import policy associated with interface ge-0/0/0.0 and places all routes from spoke PE routers that match the policy into its bgp.l3vpn routing table. (Any routes that do not match are discarded.)
5. Router D checks its VRF import policy associated with interface ge-0/0/0.0 and installs all routes that match into its spoke VRF table. The routes are installed with the spoke target community.
6. Router D announces routes to the hub CE over interface ge-0/0/0.
7. The hub CE router announces the routes back to the hub PE Router D over the second interface to the hub router, interface ge-0/0/1.
8. The hub PE router installs the routes learned from the hub CE router into its hub VRF table, which is associated with interface ge-0/0/1.
9. The hub PE router checks the VRF export policy associated with interface ge-0/0/1.0 and announces all routes that match to all spokes after adding the hub target community.

Figure 18 illustrates how routes are distributed from this spoke router to the other spoke CE router, Router CE2. The same path is followed if you issue a traceroute command from Router CE1 to Router CE2.

Figure 18: Route Distribution between Two Spoke Routers



The following sections explain how to configure the VPN functionality for a hub-and-spoke topology on the hub and spoke PE routers. The CE routers do not know about the VPN, so you configure them normally.

- Enable an IGP on the Hub and Spoke PE Routers on page 129
- Configure LDP on the Hub and Spoke PE Routers on page 129
- Configure IBGP on the PE Routers on page 130
- Configure Routing Instances for VPNs on the Hub and Spoke PE Routers on page 131
- Configure VPN Policy on the PE Routers on page 134

The final section in this example, “Hub-and-Spoke VPN Configuration Summarized by Router” on page 137, consolidates the statements needed to configure VPN functionality for each of the service provider routers shown in Figure 17.

Enable an IGP on the Hub and Spoke PE Routers

To allow the hub and spoke PE routers to exchange routing information, you must configure an IGP on all these routers or you must configure static routes. You configure the IGP on the master instance of the routing protocol process (rpd) (that is, at the [edit protocols] hierarchy level), not within the routing instance (that is, not at the [edit routing-instances] hierarchy level).

You configure the IGP in the standard way. This configuration example does not include this portion of the configuration.

In the route distribution in a hub-and-spoke topology, if the protocol used between the CE and PE routers at the hub site is BGP, the hub CE router announces all routes received from the hub PE router and the spoke routers back to the hub PE router and all the spoke routers. This means that the hub and spoke PE routers receive routes that contain their AS number. Normally, when a route contains this information, it indicates that a routing loop has occurred and the router rejects the routes. However, for the VPN configuration to work, the hub PE router and the spoke routers must accept these routes. To enable this, include the loops option when configuring the AS at the [edit routing-options] hierarchy level on the hub PE router and all the spoke routers. For this example configuration, you specify a value of 1. You can specify a number from 0 through 10.

```
[edit routing-options]
autonomous-system as-number loops 1;
```

Configure LDP on the Hub and Spoke PE Routers

You must configure LDP on the interfaces between the hub and spoke PE routers that participate in the VPN.

On hub PE Router D, configure LDP as follows:

```
[edit protocols]
ldp {
   interface so-1/0/0.0;
   interface t3-1/1/0.0;
}
```

On spoke PE Router E, configure LDP as follows:

```
[edit protocols]
ldp {
   interface fe-0/1/2.0;
}
```

On spoke PE router F, configure LDP as follows:

```
[edit protocols]
ldp {
   interface fe-1/0/0.0;
}
```

Configure IBGP on the PE Routers

On the hub and spoke PE routers, configure an IBGP session with the following properties:

- VPN family—To indicate that the IBGP session is for the VPN, include the family inet-vpn statement.
- Loopback address—Include the local-address statement, specifying the local PE router's loopback address. The IBGP session for VPNs runs through the loopback address. Note that you must also configure the lo0 interface at the [edit interfaces] hierarchy level. The example does not include this part of the router's configuration.
- Neighbor address—Include the neighbor statement. On the hub router, specify the IP address of each spoke PE router, and on the spoke router, specify the address of the hub PE router.

For the hub router, you configure an IBGP session with each spoke, and for each spoke router, you configure an IBGP session with the hub. There are no IBGP sessions between the two spoke routers.

On hub Router D, configure IBGP as follows. The first neighbor statement configures an IBGP session to spoke Router E, and the second configures a session to spoke Router F.

```
[edit protocols]
bgp {
    group Hub-to-Spokes {
        type internal;
        local-address 10.255.14.174;
        family inet-vpn {
            unicast:
        }
        neighbor 10.255.14.180;
        neighbor 10.255.14.182;
    }
}
```

On spoke Router E, configure an IBGP session to the hub router as follows:

```
[edit protocols]
bgp {
    group Spoke-E-to-Hub {
        type internal;
        local-address 10.255.14.180;
        neighbor 10.255.14.174 {
            family inet-vpn {
                unicast:
        }
    }
}
```

On spoke Router F, configure an IBGP session to the hub router as follows:

```
[edit protocols]
bgp {
    group Spoke-F-to-Hub {
        type internal;
        local-address 10.255.14.182;
        neighbor 10.255.14.174 {
            family inet-vpn {
                unicast:
            }
        }
    }
```

Configure Routing Instances for VPNs on the Hub and Spoke PE Routers

For the hub PE router to be able to distinguish between packets going to and coming from the spoke PE routers, you must configure it with two routing instances:

- One routing instance (in this example, Spokes-to-Hub-CE) is associated with the interface that carries packets from the hub PE router to the hub CE router (in this example, interface ge-0/0/0.0). Its VRF table contains the routes being announced by the spoke PE routers and the hub PE router to the hub CE router.

- The second routing instance (in this example, Hub-CE-to-Spokes) is associated with the interface that carries packets from the hub CE router to the hub PE router (in this example, interface ge-0/0/1.0). Its VRF table contains the routes being announced from the hub CE router to the hub and spoke PE routers.

On each spoke router, you must configure one routing instance.

You must define the following in the routing instance:

- Route distinguisher, which is used to distinguish the addresses in one VPN from those in another VPN.

- Instance type of vrf, which creates the VRF table on the PE router.

- Interfaces that are part of the VPN and that connect the PE routers to their CE routers.

- VRF import and export policies. Both import policies must include reference to a community. Otherwise, when you try to commit the configuration, the commit fails. (The exception to this is if the import policy contains only a then reject statement.) In the VRF export policy, spoke PE routers attach the spoke target community.

- Routing between the PE and CE routers, which is required for the PE router to distribute VPN-related routes to and from connected CE routers. You can configure a routing protocol—either BGP, OSPF, or RIP—or you can configure static routing.

For a hub-and-spoke topology, you must configure different policies in each routing instance on the hub CE router. For the routing instance associated with the interface that carries packets from the hub PE router to the hub CE router (in this example, Spokes-to-Hub-CE), the import policy must accept all routes received on the IBGP session between the hub and spoke PE routers and the export policy must reject all routes received from the hub CE router. For the routing instance associated with the interfaces that carries packets from the hub CE router to the hub PE router (in this example, Hub-CE-to-Spokes), the import policy must reject all routes received from the spoke PE routers, and the export policy must export to all the spoke routers.

On hub PE Router D, configure the following routing instances. Router D uses OSPF to distribute routes to and from the hub CE router.

```
[edit]
routing-instance {
    Spokes-to-Hub-CE {
        instance-type vrf;
        interface ge-0/0/0.0;
        route-distinguisher 10.255.1.174:65535;
        vrf-import spoke;
        vrf-export null;
        protocols {
            ospf {
                export redistribute-vpn;
                area 0.0.0.0 {
                    interface ge-0/0/0;
                }
            }
        }
    }
    Hub-CE-to-Spokes {
        instance-type vrf;
        interface ge-0/0/1.0;
        route-distinguisher 10.255.1.174:65535;
        vrf-import null;
        vrf-export hub;
        protocols {
            ospf {
                export redistribute-vpn;
                area 0.0.0.0 {
                    interface ge-0/0/1.0;
                }
            }
        }
    }
}
```

On spoke PE Router E, configure the following routing instances. Router E uses OSPF to distribute routes to and from the spoke CE router CE1.

```
[edit]
routing-instance {
    Spoke-E-to-Hub {
        instance-type vrf;
        interface fe-0/1/0.0;
        route-distinguisher 10.255.14.80:65535;
        vrf-import hub;
        vrf-export spoke;
        protocols {
            ospf {
                export redistribute-vpn;
                area 0.0.0.0 {
                    interface fe-0/1/0.0;
                ]
            }
        }
    }
}
```

On spoke PE Router F, configure the following routing instances. Router F uses OSPF to distribute routes to and from the spoke CE router CE2.

```
[edit]
routing-instance {
    Spoke-F-to-Hub {
        instance-type vrf;
        interface fe-1/0/1.0;
        route-distinguisher 10.255.14.182:65535;
        vrf-import hub;
        vrf-export spoke;
        protocols {
            ospf {
                export redistribute-vpn;
                area 0.0.0.0 {
                    interface fe-1/0/1.0;
                ]
            }
        }
    }
}
```

Configure VPN Policy on the PE Routers

You must configure VPN import and export policies on each of the hub and spoke PE routers so that they install the appropriate routes in the VRF tables, which they use to forward packets within each VPN.

On the spoke routers, you define policies to exchange routes with the hub router.

On the hub router, you define policies to accept routes from the spoke PE routers and distribute them to the hub CE router, and vice versa. The hub PE router has two VRF tables:

- Spoke-to-hub VRF table—Handles routes received from spoke routers and announces these routes to the hub CE router. For this VRF table, the import policy must check that the spoke target name is present and that the route was received from the IBGP session between the hub PE and the spoke PE routers. This VRF table must not export any routes, so its export policy should reject everything.

- Hub-to-spoke VRF table—Handles routes received from the hub CE router and announces them to the spoke routers. For this VRF table, the export policy must add the hub target community. This VRF table must not import any routes, so its import policy should reject everything.

In the VPN policy, you also configure the VPN target communities.

On hub PE Router D, configure the following policies to apply to the VRF tables:

- spoke—Accepts routes received from the IBGP session between it and the spoke PE routers that contain the community target spoke, and rejects all other routes.

- hub—Adds the community target hub to all routes received from OSPF (that is, from the session between it and the hub CE router). It rejects all other routes.

- null—Rejects all routes.

- redistribute-vpn—Redistributes OSPF routes to neighbors within the routing instance.

```
[edit]
policy-options {
    policy-statement spoke {
        term a {
            from {
                protocol bgp;
                community spoke;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
```

```
        policy-statement hub {
            term a {
                from protocol ospf;
                then {
                    community add hub;
                    accept;
                }
            }
            term b {
                then reject;
            }
        }
        policy-statement null {
            then reject;
        }
        policy-statement redistribute-vpn {
            term a {
                from protocol bgp;
                then accept;
            }
            term b {
                then reject;
            }
        }
        community hub members target:65535:1;
        community spoke members target:65535:2;
    }
```

To apply the VRF policies on Router D, include the vrf-export and vrf-import statements when you configure the routing instances:

```
    [edit]
    routing-instance {
        Spokes-to-Hub-CE {
            vrf-import spoke;
            vrf-export null;
        }
        Hub-CE-to-Spokes {
            vrf-import null;
            vrf-export hub;
        }
    }
```

On spoke PE Router E and Router F, configure the following policies to apply to the VRF tables:

- hub—Accepts routes received from the IBGP session between it and the hub PE routers that contain the community target hub, and rejects all other routes.

- spoke—Adds the community target spoke to all routes received from OSPF (that is, from the session between it and the hub CE router) and rejects all other routes.

- redistribute-vpn—Redistributes OSPF routes to neighbors within the routing instance.

On spoke PE Router E and Router F, configure the following VPN import and export policies:

```
[edit]
policy-options {
    policy-statement hub {
        term a {
            from {
                protocol bgp;
                community hub;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement spoke {
        term a {
            from protocol ospf;
            then {
                community add spoke;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement redistribute-vpn {
        term a {
            from protocol bgp;
            then accept;
        }
        term b {
            then reject;
        }
    }
    community hub members target:65535:1;
    community spoke members target 65535:2;
}
```

To apply the VRF policies on the spoke routers, include the vrf-export and vrf-import statements when you configure the routing instances:

```
[edit]
routing-instance {
    Spoke-E-to-Hub {
        vrf-import hub;
        vrf-export spoke;
    }
}

[edit]
routing-instance {
    Spoke-F-to-Hub {
        vrf-import hub;
        vrf-export spoke;
    }
}
```

Hub-and-Spoke VPN Configuration Summarized by Router

Router D (Hub PE Router)

Routing Instance for Distributing Spoke Routes to Hub CE

```
routing-instance {
    Spokes-to-Hub-CE {
        instance-type vrf;
        interface ge-0/0/0.0;
        route-distinguisher 10.255.1.174:65535;
        vrf-import spoke;
        vrf-export null;
```

Instance Routing Protocol

```
        protocols {
            ospf {
                export redistribute-vpn;
                area 0.0.0.0 {
                    interface ge-0/0/0;
                }
            }
        }
    }
```

Routing Instance for Distributing Hub CE Routes to Spokes

```
    Hub-CE-to-Spokes {
        instance-type vrf;
        interface ge-0/0/1.0;
        route-distinguisher 10.255.1.174:65535;
        vrf-import null;
        vrf-export hub;
```

Instance Routing Protocols

```
        protocols {
            ospf {
                export redistribute-vpn;
                area 0.0.0.0 {
                    interface ge-0/0/1.0;
                }
            }
        }
    }
}
```

Routing Options (Master Instance)

```
routing-options {
    autonomous-system 1 loops 1;
}
```

Protocols (Master Instance)

```
protocols {
```

Enable LDP

```
    ldp {
        interface so-1/0/0.0;
        interface t3-1/1/0.0;
    }
```

Configure IBGP

```
bgp {
    group Hub-to-Spokes {
        type internal;
        local-address 10.255.14.174;
        family inet-vpn {
            unicast:
        }
        neighbor 10.255.14.180;
        neighbor 10.255.14.182;
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement spoke {
        term a {
            from {
                protocol bgp;
                community spoke;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement hub {
        term a {
            from protocol ospf;
            then {
                community add hub;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement null {
        then reject;
    }
    policy-statement redistribute-vpn {
        term a {
            from protocol bgp;
            then accept;
        }
        term b {
            then reject;
        }
    }
    community hub members target:65535:1;
    community spoke members target:65535:2;
}
```

Router E (Spoke PE Router)

Routing Instance

```
routing-instance {
    Spoke-E-to-Hub {
        instance-type vrf;
        interface fe-0/1/0.0;
        route-distinguisher 10.255.14.80:65535;
        vrf-import hub;
        vrf-export spoke;
```

Instance Routing Protocol

```
        protocols {
            ospf {
                export redistribute-vpn;
                area 0.0.0.0 {
                    interface fe-0/1/0.0;
                ]
            }
        }
    }
}
```

Routing Options (Master Instance)

```
routing-options {
    autonomous-system 1 loops 1;
}
```

Protocols (Master Instance)

```
protocols {
```

Enable LDP

```
    ldp {
    interface fe-0/1/2.0;
    }
```

Configure IBGP

```
    bgp {
        group Spoke-E-to-Hub {
            type internal;
            local-address 10.255.14.180;
            neighbor 10.255.14.174 {
                family inet-vpn {
                    unicast:
                }
            }
        }
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement hub {
        term a {
            from {
                protocol bgp;
                community hub;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement spoke {
        term a {
            from protocol ospf;
            then {
                community add spoke;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement redistribute-vpn {
        term a {
            from protocol bgp;
            then accept;
        }
        term b {
            then reject;
        }
    }
    community hub members target:65535:1;
    community spoke members target:65535:2;
}
```

Router F (Spoke PE Router)

Routing Instance

```
routing-instance {
    Spoke-F-to-Hub {
        instance-type vrf;
        interface fe-1/0/1.0;
        route-distinguisher 10.255.14.182:65535;
        vrf-import hub;
        vrf-export spoke;
```

Instance Routing Protocol

```
        protocols {
            ospf {
                export redistribute-vpn;
                area 0.0.0.0 {
                    interface fe-1/0/1.0;
                ]
            }
        }
    }
}
```

Routing Options (Master Instance)

```
routing-options {
    autonomous-system 1 loops 1;
}
```

Protocols (Master Instance)

```
protocols {
```

Enable LDP

```
    ldp {
        interface fe-1/0/0.0;
    }
```

Configure IBGP

```
    bgp {
        group Spoke-F-to-Hub {
            type internal;
            local-address 10.255.14.182;
            neighbor 10.255.14.174 {
                family inet-vpn {
                    unicast:
                }
            }
        }
    }
}
```

Configure VPN Policy

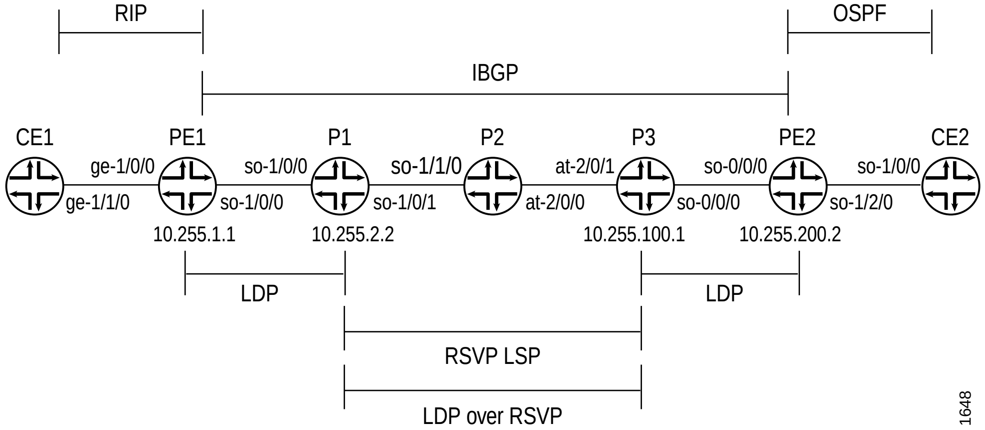
```
policy-options {
    policy-statement hub {
        term a {
            from {
                protocol bgp;
                community hub;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement spoke {
        term a {
            from protocol ospf;
            then {
                community add spoke;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement redistribute-vpn {
        term a {
            from {
                protocol bgp;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    community hub members target:65535:1;
    community spoke members target:65535:2;
}
```

Configure an LDP-over-RSVP VPN Topology

This example shows how to set up a VPN topology in which LDP packets are tunneled over an RSVP LSP. This configuration consists of the following components (see Figure 19):

- One VPN (VPN-A)
- Two PE routers
- LDP as the signaling protocol between the PE routers and their adjacent provider routers
- An RSVP LSP between two of the provider routers over which LDP is tunneled

Figure 19: Example of an LDP-over-RSVP VPN Topology



The following steps describe how this topology is established and how packets are sent from CE Router CE2 to CE Router CE1:

1. The provider routers P1 and P3 establish RSVP LSPs between each other and install their loopback addresses in their inet.3 routing tables.
2. PE Router PE1 establishes an LDP session with Router P1 over interface so-1/0/0.0.
3. Router P1 establishes an LDP session with Router P3's loopback address, which is reachable using the RSVP LSP.
4. Router P1 sends its label bindings, which include a label to reach Router PE1, to Router P3. These label bindings allow Router P3 to direct LDP packets to Router PE1.
5. Router P3 establishes an LDP session with Router PE2 over interface so0-0/0/0.0 and establishes an LDP session with Router P1's loopback address.
6. Router P3 sends its label bindings, which include a label to reach Router PE2, to Router P1. These label bindings allow Router P1 to direct LDP packets to Router PE2's loopback address.
7. Routers PE1 and PE2 establish IBGP sessions with each other.

8. When Router PE1 announces to Router PE2 routes that it learned from Router CE1, it includes its VPN label. (The PE router creates the VPN label and binds it to the interface between the PE and CE routers.) Similarly, when Router PE2 announces routes that it learned from Router CE2, it sends its VPN label to Router PE1.

   When Router PE2 wants to forward a packet to Router CE1, it pushes two labels onto the packet's label stack: first, the VPN label that is bound to the interface between Router PE1 and Router CE1, then the LDP label used to reach Router PE1. Then it forwards the packets to Router P3 over interface `so-0/0/1.0`.

9. When Router P3 receives the packets from Router PE2, it swaps the LDP label that is on top of the stack (according to its LDP database) and also pushes an RSVP label onto the top of the stack so that the packet can now be switched by the RSVP LSP. At this point, there are three labels on the stack: the inner (bottom) label is the VPN label, the middle is the LDP label, and the outer (top) is the RSVP label.

10. Router P2 receives the packet and switches it to Router P1 by swapping the RSVP label. In this topology, because Router P2 is the penultimate-hop router in the LSP, it pops the RSVP label and forwards the packet over interface `so-1/1/0.0` to Router P1. At this point, there are two labels on the stack: the inner label is the VPN label and the outer one is the LDP label.

11. When Router P1 receives the packet, it pops the outer label (the LDP label) and forwards the packet to Router PE1 using interface `so-1/0/0.0`. In this topology, Router PE1 is the egress LDP router, so Router P1 pops the LDP label instead of swapping it with another label. At this point, there is only one label on the stack, the VPN label.

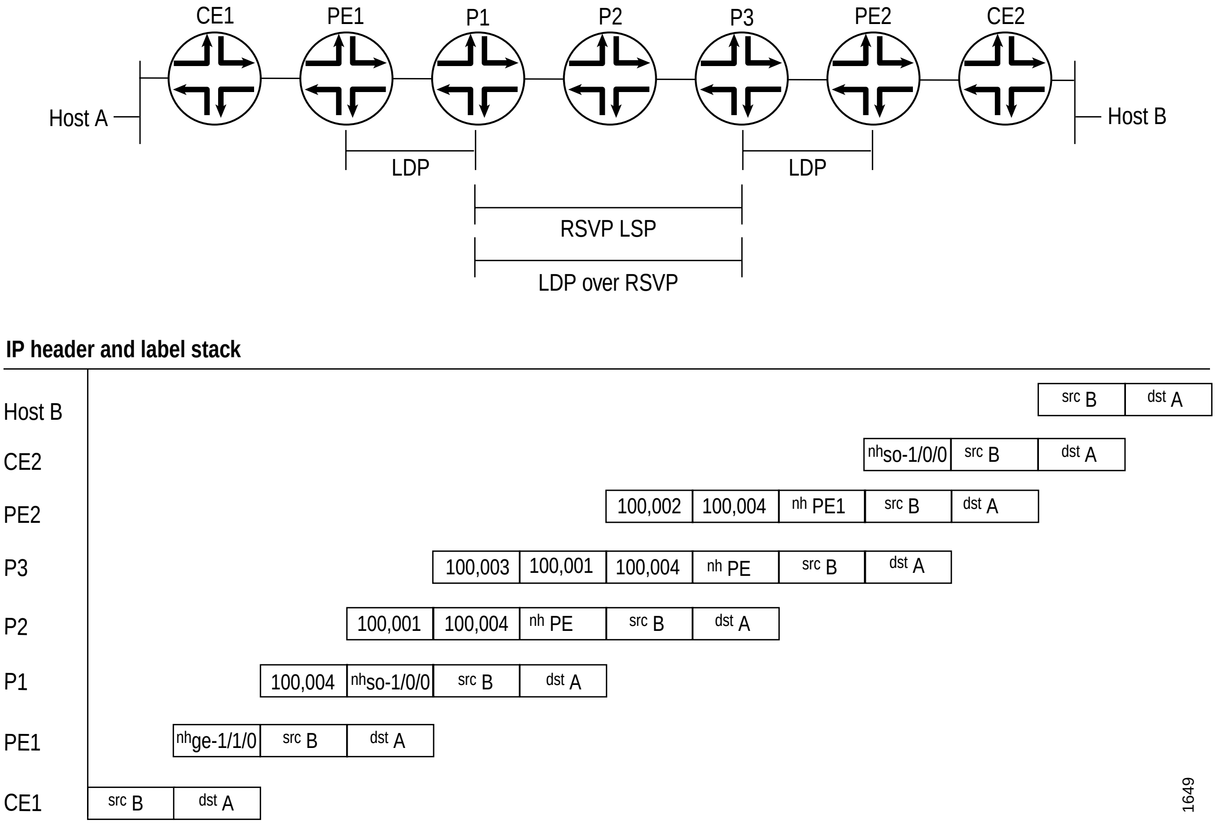
12. When Router PE1 receives the packet, it pops the VPN label and forwards the packet as an IPv4 packet to Router CE1 over interface `ge-1/1/0.0`.

A similar set of operations occurs for packets sent from Router CE1 that are destined for Router CE2.

The following list explains how, for packets being sent from Router CE2 to Router CE1, the LDP, RSVP, and VPN labels are announced by the various routers. These steps include examples of label values (illustrated in Figure 20).

- LDP labels
  - Router PE1 announces LDP label 3 for itself to Router P1.
  - Router P1 announces LDP label 100,001 for Router PE1 to Router P3.
  - Router P3 announces LDP label 100,002 for Router PE1 to Router PE2.
- RSVP labels
  - Router P1 announces RSVP label 3 to Router P2.
  - Router P2 announces RSVP label 100,003 to Router P3.
- VPN label
  - Router PE1 announces VPN label 100,004 to Router PE2 for the route from Router CE1 to Router CE2.

Figure 20: Label Pushing and Popping


CE1
PE1
P1
P2
P3
PE2
CE2
Host A
Host B
LDP
LDP
RSVP LSP
LDP over RSVP
IP header and label stack
Host B: src B | dst A
CE2: nh so-1/0/0 | src B | dst A
PE2: 100,002 | 100,004 | nh PE1 | src B | dst A
P3: 100,003 | 100,001 | 100,004 | nh PE | src B | dst A
P2: 100,001 | 100,004 | nh PE | src B | dst A
P1: 100,004 | nh so-1/0/0 | src B | dst A
PE1: nh ge-1/1/0 | src B | dst A
CE1: src B | dst A
1649

For a packet sent from Host B in Figure 20 to Host A, the packet headers and labels change as follows as the packet travels to its destination:

1. The packet that originates from Host B has a source address of B and a destination address of A in its header.

2. Router CE2 adds to the packet a next hop of interface so-1/0/0.

3. Router PE2 swaps out the next hop of interface so-1/0/0 and replaces it with a next hop of PE1. It also adds two labels for reaching Router PE1, first the VPN label (100,004), then the LDP label (100,002). The VPN label is thus the inner (bottom) label on the stack, and the LDP label is the outer label.

4. Router P3 swaps out the LDP label added by Router PE2 (100,002) and replaces it with its LDP label for reaching Router PE1 (100,001). It also adds the RSVP label for reaching Router P2 (100,003).

5. Router P2 removes the RSVP label (100,003) because it is the penultimate hop in the MPLS LSP.

6. Router P1 removes the LDP label (100,001) because it is the penultimate LDP router. It also swaps out the next hop of PE1 and replaces it with the next hop interface, so-1/0/0.

7. Router PE1 removes the VPN label (100,004). It also swaps out the next hop interface of so-1/0/0 and replaces it with its next hop interface, ge-1/1/0.

8. Router CE1 removes the next hop interface of ge-1/1/0, and the packet header now contains just a source address of B and a destination address of A.

The following sections explain how to configure the VPN functionality on the PE and provider routers. The CE routers are not aware of the VPN, so you configure them normally.

- Enable an IGP on the PE and Provider Routers on page 145
- Enable LDP on the PE and Provider Routers on page 146
- Enable RSVP and MPLS on the Provider Router on page 147
- Configure the MPLS LSP Tunnel between the Provider Routers on page 147
- Configure IBGP on the PE Routers on page 148
- Configure Routing Instances for VPNs on the PE Routers on page 149
- Configure VPN Policy on the PE Routers on page 151

The final section in this example, "LDP-over-MPLS VPN Configuration Summarized by Router" on page 152, consolidates the statements needed to configure VPN functionality on each of the service provider routers shown in Figure 19.

> Note
>
> In this example, a private AS number is used for the route distinguisher and the route target. This number is used for illustration only. When you are configuring VPNs, you should use an assigned AS number.

Enable an IGP on the PE and Provider Routers

To allow the PE and provider routers to exchange routing information among themselves, you must configure an IGP on all these routers or you must configure static routes. You configure the IGP on the master instance of the routing protocol process (rpd) (that is, at the [edit protocols] hierarchy level), not within the VPN routing instance (that is, not at the [edit routing-instances] hierarchy level).

You configure the IGP in the standard way. This configuration example does not include this portion of the configuration.

Enable LDP on the PE and Provider Routers

In this configuration example, the Label Distribution Protocol (LDP) is the signaling protocol between the PE routers. For the VPN to function, you must configure LDP on the two PE routers and on the provider routers that are connected to the PE routers. You need to configure LDP only on the interfaces in the core of the service provider's network; that is, between the PE and provider routers and between the provider routers. You do not need to configure LDP on the interface between the PE and CE routers.

In this configuration example, you configure LDP on the provider routers' loopback interfaces because these are the interfaces on which the MPLS LSP is configured.

On the PE routers, you must also configure family inet when you configure the logical interface.

On Router PE1, configure LDP as follows:

```
[edit protocols]
ldp {
    interface so-1/0/0.0;
}
[edit interfaces]
so-1/0/0 {
    unit 0 {
        family mpls;
    }
}
```

On Router PE2, configure LDP as follows:

```
[edit protocols]
ldp {
    interface so-0/0/0.0;
}
[edit interfaces]
so-0/0/1 {
    unit 0 {
        family mpls;
    }
}
```

On Router P1, configure LDP as follows:

```
[edit protocols]
ldp {
    interface so-1/0/0.0;
    interface lo0;
}
```

On Router P3, configure LDP as follows:

```
[edit protocols]
ldp {
    interface lo0;
    interface so-0/0/0.0;
}
```

On Router P2, although you do not need to configure LDP, you can optionally configure it to provide a fallback LDP path in case the RSVP LSP becomes nonoperational:

```
[edit protocols]
ldp {
    interface so-1/1/0.0;
    interface at-2/0/0.0;
}
```

Enable RSVP and MPLS on the Provider Router

On the provider router, P2, you must configure the Resource Reservation Protocol (RSVP) and Multiprotocol Label Switching (MPLS) because this router exists on the MPLS LSP path between the provider Routers P1 and P3:

```
[edit]
protocols {
    rsvp {
        interface so-1/1/0.0;
        interface at-2/0/0.0;
    }
    mpls {
        interface so-1/1/0.0;
        interface at-2/0/0.0;
    }
}
```

Configure the MPLS LSP Tunnel between the Provider Routers

In this configuration example, LDP is tunneled over an RSVP LSP. Therefore, in addition to configuring RSVP, you must enable traffic engineering support in an IGP and you must create an MPLS LSP to tunnel the LDP traffic.

On Router P1, enable RSVP and configure one end of the MPLS LSP tunnel. In this example, traffic engineering support is enabled for OSPF, and you configure MPLS on the interfaces to the LSP and to Router PE1. In the to statement, you specify the loopback address of Router P3.

```
[edit]
protocols {
    rsvp {
        interface so-1/0/1.0;
    }
    mpls {
        label-switched-path P1-to-P3 {
            to 10.255.100.1;
            ldp-tunneling;
        }
        interface so-1/0/0.0;
        interface so-1/0/1.0;
    }
```

```
        ospf {
            traffic-engineering;
            area 0.0.0.0 {
                interface so-1/0/0.0;
                interface so-1/0/1.0;
            }
        }
    }
```

On Router P3, enable RSVP and configure the other end of the MPLS LSP tunnel. Again, traffic engineering support is enabled for OSPF, and you configure MPLS on the interfaces to the LSP and to Router PE2. In the to statement, you specify the loopback address of Router P1.

```
    [edit]
    protocols {
        rsvp {
            interface at-2/0/1.0;
        }
        mpls {
            label-switched-path P3-to-P1 {
                to 10.255.2.2;
                ldp-tunneling;
            }
            interface at-2/0/1.0;
            interface so-0/0/0.0;
        }
        ospf {
            traffic-engineering;
            area 0.0.0.0 {
                interface at-2/0/1.0;
                interface so-0/0/0.0;
            }
        }
    }
```

Configure IBGP on the PE Routers

On the PE routers, configure an IBGP session with the following properties:

- VPN family—To indicate that the IBGP session is for the VPN, include the family inet-vpn statement.
- Loopback address—Include the local-address statement, specifying the local PE router's loopback address. The IBGP session for VPNs runs through the loopback address. Note that you must also configure the lo0 interface at the [edit interfaces] hierarchy level. The example does not include this part of the router's configuration.
- Neighbor address—Include the neighbor statement, specifying the IP address of the neighboring PE router, which is its loopback (lo0) address.

On Router PE1, configure IBGP as follows:

```
[edit]
protocols {
    bgp {
        group PE1-to-PE2 {
            type internal;
            local-address 10.255.1.1;
            family inet-vpn {
                unicast:
            }
            neighbor 10.255.200.2;
        }
    }
}
```

On Router PE2, configure IBGP as follows:

```
[edit]
protocols {
    bgp {
        group PE2-to-PE1 {
            type internal;
            local-address 10.255.200.2;
            family inet-vpn {
                unicast:
            }
            neighbor 10.255.1.1;
        }
    }
}
```

Configure Routing Instances for VPNs on the PE Routers

Both PE routers service VPN-A, so you must configure one routing instance on each router for the VPN in which you define the following:

- Route distinguisher, which must be unique for each routing instance on the PE router. It is used to distinguish the addresses in one VPN from those in another VPN.
- Instance type of vrf, which creates the VRF table on the PE router.
- Interfaces connected to the CE routers.

- VRF import and export policies, which must be the same on each PE router that services the same VPN. Unless the import policy contains only a then reject statement, it must include reference to a community. Otherwise, when you try to commit the configuration, the commit fails.

> **Note**
>
> In this example, a private AS number is used for the route distinguisher. This number is used for illustration only. When you are configuring VPNs, you should use an assigned AS number.

- Routing between the PE and CE routers, which is required for the PE router to distribute VPN-related routes to and from connected CE routers. You can configure a routing protocol—either BGP, OSPF, or RIP—or you can configure static routing.

On Router PE1, configure the following routing instance for VPN-A. In this example, Router PE1 uses RIP to distribute routes to and from the CE router to which it is connected.

```
[edit]
routing-instance {
    VPN-A {
        instance-type vrf;
        interface ge-1/0/0.0;
        route-distinguisher 65535:0;
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
        protocols {
            rip {
                group PE1-to-CE1 {
                    neighbor ge-1/0/0.0;
                }
            }
        }
    }
}
```

On Router PE2, configure the following routing instance for VPN-A. In this example, Router PE2 uses OSPF to distribute routes to and from the CE router to which it is connected.

```
[edit]
routing-instance {
    VPN-A {
        instance-type vrf;
        interface so-1/2/0.0;
        route-distinguisher 65535:1;
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
        protocols {
            ospf {
                area 0.0.0.0 {
                    interface so-1/2/0.0;
                }
            }
        }
    }
}
```

Configure VPN Policy on the PE Routers

You must configure VPN import and export policies on each of the PE routers so that they install the appropriate routes in their VRF tables, which they use to forward packets within a VPN. For VPN-A, the VRF table is VPN-A.inet.0.

In the VPN policy, you also configure VPN target communities.

Note

In this example, a private AS number is used for the route target. This number is used for illustration only. When you are configuring VPNs, you should use an assigned AS number.

On Router PE1, configure the following VPN import and export policies.

Note

The policy qualifiers shown in this example are only those needed for the VPN to function. You can configure additional qualifiers, as needed, to any policies that you configure.

```
[edit]
policy-options {
    policy-statement VPN-A-import {
        term a {
            from {
                protocol bgp;
                community VPN-A;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-A-export {
        term a {
            from protocol rip;
            then {
                community add VPN-A;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community VPN-A members target:65535:00;
}
```

On Router PE2, configure the following VPN import and export policies:

```
[edit]
policy-options {
    policy-statement VPN-A-import {
        term a {
            from {
                protocol bgp;
                community VPN-A;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-A-export {
        term a {
            from protocol ospf;
            then {
                community add VPN-A;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community VPN-A members target:65535:00;
}
```

To apply the VPN policies on the routers, include the vrf-export and vrf-import statements when you configure the routing instance on the PE routers. The VRF import and export policies handle the route distribution across the IBGP session running between the PE routers.

LDP-over-MPLS VPN Configuration Summarized by Router

Router PE1

Routing Instance for VPN-A

```
routing-instance {
    VPN-A {
        instance-type vrf;
        interface ge-1/0/0.0;
        route-distinguisher 65535:0;
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
```

Instance Routing Protocol

```
        protocols {
            rip {
                group PE1-to-CE1 {
                    neighbor ge-1/0/0.0;
                }
            }
        }
    }
}
```

Interfaces

```
interfaces {
    so-1/0/0 {
        unit 0 {
            family mpls;
        }
    ]
    ge-1/0/0 {
        unit 0 {
            family mpls;
        }
    }
}
```

Master Protocol Instance

```
protocols {
```

Enable LDP

```
    ldp {
        interface so-1/0/0.0;
    }
```

Enable MPLS

```
    mpls {
        interface so-1/0/0.0;
        interface ge-1/0/0.0;
    }
```

Configure IBGP

```
    bgp {
        group PE1-to-PE2 {
            type internal;
            local-address 10.255.1.1;
            family inet-vpn {
                unicast:
            }
            neighbor 10.255.100.1;
        }
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement VPN-A-import {
        term a {
            from {
                protocol bgp;
                community VPN-A;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-A-export {
        term a {
            from protocol rip;
            then {
                community add VPN-A;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community VPN-A members target:65535:00;
}
```

Router P1

Master Protocol Instance

```
protocols {
```

Enable RSVP

```
    rsvp {
        interface so-1/0/1.0;
    }
```

Enable LDP

```
    ldp {
        interface so-1/0/0.0;
        interface lo0.0;
    }
```

Enable MPLS

```
    mpls {
        label-switched-path P1-to-P3 {
            to 10.255.100.1;
            ldp-tunneling;
        }
        interface so-1/0/0.0;
        interface so-1/0/1.0;
    }
```

Configure OSPF for Traffic Engineering Support

```
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-1/0/0.0;
            interface so-1/0/1.0;
        }
    }
}
```

Router P2

Master Protocol Instance

```
protocols {
```

Enable RSVP

```
    rsvp {
        interface so-1/1/0.0;
        interface at-2/0/0.0;
    }
```

Enable MPLS

```
    mpls {
        interface so-1/1/0.0;
        interface at-2/0/0.0;
    }
}
```

Router P3

Master Protocol Instance

```
protocols {
```

Enable RSVP

```
    rsvp {
        interface at-2/0/1.0;
    }
```

Enable LDP

```
    ldp {
        interface so-0/0/0.0;
        interface lo0.0;
    }
```

Enable MPLS

```
    mpls {
        label-switched-path P3-to-P1 {
            to 10.255.2.2;
            ldp-tunneling;
        }
        interface at-2/0/1.0;
        interface so-0/0/0.0;
    }
```

Configure OSPF for Traffic Engineering Support

```
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface at-2/0/1.0;
            interface at-2/0/1.0;
        }
    }
}
```

Router PE2

Routing Instance for VPN-A

```
routing-instance {
    VPN-A {
        instance-type vrf;
        interface so-1/2/0.0;
        route-distinguisher 65535:1;
        vrf-import VPN-A-import;
        vrf-export VPN-A-export;
```

Instance Routing Protocol

```
        protocols {
            ospf {
                area 0.0.0.0 {
                    interface so-1/2/0.0;
                }
            }
        }
    }
}
```

Interfaces

```
interfaces {
    so-0/0/0 {
        unit 0 {
            family mpls;
        }
    ]
    so-1/2/0 {
        unit 0 {
            family mpls;
        }
    }
}
```

Master Protocol Instance

```
protocols {
```

Enable LDP

```
    ldp {
        interface so-0/0/0.0;
    }
```

Enable MPLS

```
    mpls {
        interface so-0/0/0.0;
        interface so-1/2/0.0;
    }
```

Configure IBGP

```
    bgp {
        group PE2-to-PE1 {
            type internal;
            local-address 10.255.200.2;
            family inet-vpn {
                unicast:
            }
            neighbor 10.255.1.1;
        }
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement VPN-A-import {
        term a {
            from {
                protocol bgp;
                community VPN-A;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement VPN-A-export {
        term a {
            from protocol ospf;
            then {
                community add VPN-A;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community VPN-A members target:65535:01;
}
```

Configure an Application-Based Layer 3 VPN Topology

This example illustrates an application-based mechanism for forwarding traffic into a Layer 3 VPN. Typically, one or more interfaces are associated with, or bound to, a VPN by including them in the configuration of the VPN routing instance. By binding the interface to the VPN, the VPN's VRF table is used to make forwarding decisions for any incoming traffic on that interface. Binding the interface also includes the interface local routes in the VRF, which provides next-hop resolution for VRF routes.

In this example, a firewall filter is used to define which incoming traffic on an interface is forwarded using the standard routing table, inet.0, and which incoming traffic is forwarded using the VRF table. You can expand this example such that incoming traffic on an interface can be redirected to one or more VPNs. For example, you can define a configuration to support a VPN that forwards traffic based on source address, that forwards HTTP traffic, or that forwards only streaming media.

For this configuration to work, the following must be true:

- The interfaces that use filter-based forwarding must not be bound to the VPN.
- Static routing must be used as the means of routing.
- You must define an interface routing table group that is shared among inet.0 and the VRFs to provide local routes to the VRF.

This example consists of two client hosts (Client D and Client E) that are in two different VPNs and that want to send traffic both within the VPN and to the Internet. The paths are defined as follows:

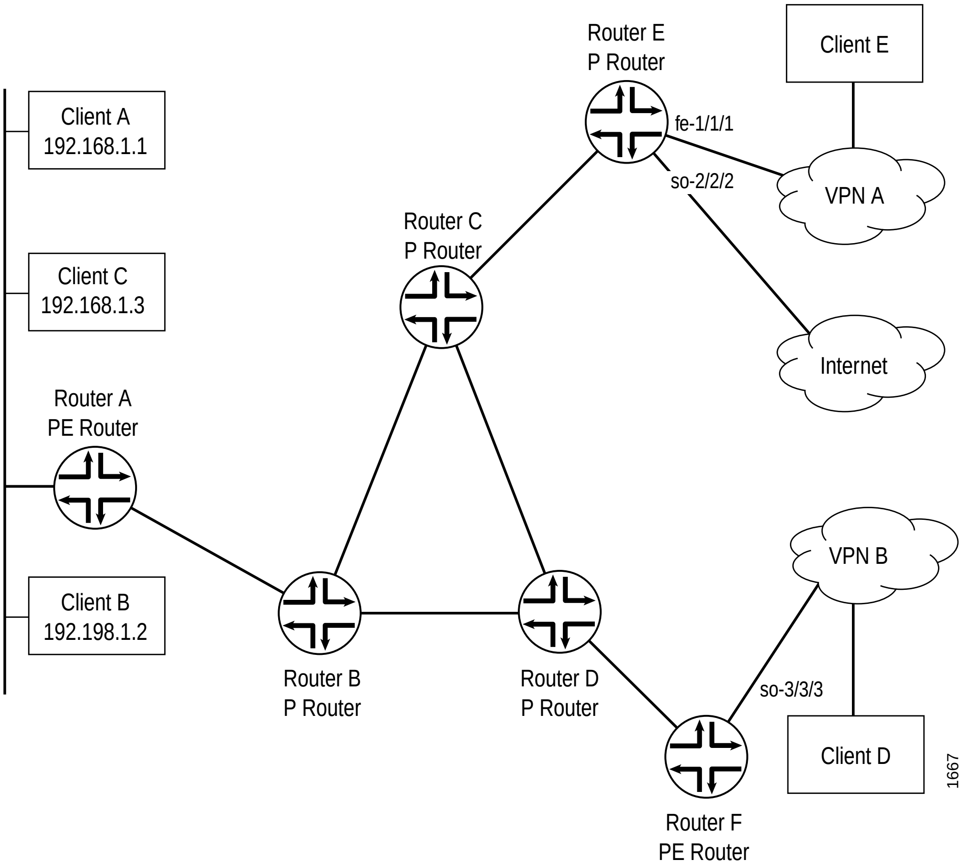
- Client A sends traffic to Client E over VPN A with a return path that also uses VPN A (using the VPN's VRF table).
- Client B sends traffic to Client D over VPN B with a return path that uses standard destination-based routing (using the inet.0 routing table).
- Clients B and C send traffic to the Internet using standard routing (using the inet.0 routing table), with a return path that also uses standard routing.

This example illustrates that there are a large variety of options in configuring an application-based Layer 3 VPN topology. This flexibility has application in many network implementations requiring specific traffic to be forwarded in a constrained routing environment.

This configuration example shows only the portions of the configuration for the filter-based forwarding, routing instances, and policy. It does not illustrate how to configure a Layer 3 VPN.

Figure 21 illustrates the configuration used in this example.

Figure 21: Application-Based Layer 3 VPN Example Configuration



Configuration on Router A

On Router A, you configure the interface to Clients A, B, and C. The configuration evaluates incoming traffic to determine whether it is to be forwarded using the VPN or using standard destination-based routing.

First, you apply an inbound filter and configure the interface to support MPLS.

```
[edit]
interfaces {
    fe-1/1/0 {
        unit 0 {
            family inet {
                filter {
                    input fbf-vrf;
                }
                address 192.168.1.1/24;
            }
            family mpls;
        }
    }
}
```

Because the interfaces that use filter-based forwarding must not be bound to a VPN, you must configure an alternate method to provide next-hop routes to the VRF table. You do this by defining an interface routing table group and sharing this group among all the routing tables. To provide a route back to the clients for normal inet.0 routing, you define a static route to include in inet.0 and redistribute the static route into BGP.

```
[edit]
routing-options {
    interface-routes {
        rib-group inet if-rib;
    }
    static {
        route 192.168.1.0/24 next-hop fe-1/1/0.0
    }
    rib-groups {
        if-rib {
            import-rib [ inet.0 vpn-A.inet.0 vpn-B.inet.0 ];
        }
    }
}
```

You apply the following filter to incoming traffic on interface fe-1/1/0.0. The first term matches traffic from Client A and forwards it to the routing instance for VPN A. The second term matches traffic from Client B that is destined for Client D and forwards it to the routing instance for VPN B. The third term matches all other traffic, which is forwarded normally using destination-based forwarding according to the routes in inet.0.

```
[edit firewall family family-name]
filter fbf-vrf {
    term vpnA {
        from {
            source-address {
                192.168.1.1/32;
            }
        }
        then {
            routing-instance vpn-A;
        }
    }
    term vpnB {
        from {
            source-address {
                192.168.1.2/32;
            }
            destination-address {
                192.168.3.0/24;
            }
        }
        then routing-instance vpn-B;
        }
    }
    term internet {
        then accept;
    }
}
```

You then configure the routing instances for VPN A and VPN B. Notice that these statements include all the required statements to define a Layer 3 VPN except for the interface statement.

```
[edit]
routing-instances {
    vpn-A {
        instance-type vrf;
        route-distinguisher 172.21.10.63:100;
        vrf-import vpn-A-import;
        vrf-export vpn-A-export;
        routing-options {
            static {
                route 192.168.1.0/24 next-hop fe-1/1/0.0;
            }
        }
    }
    vpn-B {
        instance-type vrf;
        route-distinguisher 172.21.10.63:200;
        vrf-import vpn-B-import;
        vrf-export vpn-B-export;
        routing-options {
            static {
                route 192.168.1.0/24 next-hop fe-1/1/0.0;
            }
        }
    }
}
```

Configuration on Router E

On Router E, you configure a default route to reach the Internet. You should inject this route into the local IBGP mesh to provide an exit point from the network.

```
[edit]
routing-options {
    static {
        route 0.0.0.0/0 next-hop so-2/2/2.0 discard
    }
}
```

You configure the interface to Client E such that all incoming traffic on interface fe-1/1/1.0 that matches the VPN policy is forwarded over VPN A:

```
[edit]
routing-instances {
    vpn-A {
        interface fe-1/1/1.0
        instance-type vrf;
        route-distinguisher 172.21.10.62:100;
        vrf-import vpn-A-import;
        vrf-export vpn-A-export;
        routing-options {
            static {
                route 192.168.2.0/24 next-hop fe-1/1/1.0;
            }
        }
    }
}
```

Configuration for Router F

Again, because the interfaces that use filter-based forwarding must not be bound to a VPN, you configure an alternate method to provide next-hop routes to the VRF table by defining an interface routing table group and sharing this group among all the routing tables. To provide a route back to the clients for normal inet.0 routing, you define a static route to include in inet.0 and redistribute the static route into BGP.

```
[edit]
routing-options {
    interface-routes {
        rib-group inet if-rib;
    }
    rib-groups {
        if-rib {
            import-rib [ inet.0 vpn-B.inet.0];
        }
    }
}
```

To direct traffic from VPN B to Client D, you configure the routing instance for VPN B on Router F. All incoming traffic from Client D on interface so-3/3/3.0 is forwarded normally using the destination address based on the routes in inet.0.

```
[edit]
routing-instances {
    vpn-B {
        instance-type vrf;
        route-distinguisher 172.21.10.64:200;
        vrf-import vpn-B-import;
        vrf-export vpn-B-export;
        routing-options {
            static {
                route 192.168.3.0/24 next-hop so-3/3/3.0;
            }
        }
    }
}
```

Configure an OSPF Domain ID for a Layer 3 VPN

This example illustrates how to configure an OSPF domain ID for a VPN using OSPF as the routing protocol between the PE and CE routers. Routes from an OSPF domain need an OSPF domain ID when they are distributed in BGP as VPN-IPv4 routes in VPNs with multiple OSPF domains. In a VPN connecting multiple OSPF domains, the routes from one domain might overlap with the routes of another.

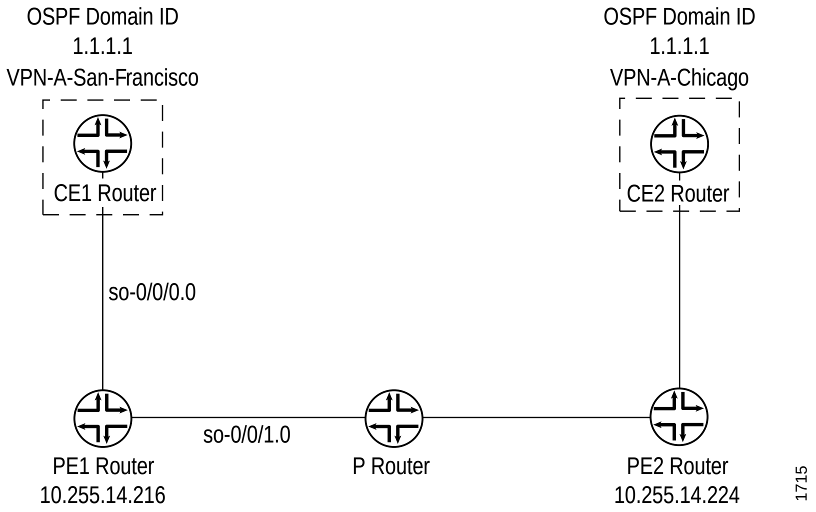
Configuring a unique OSPF domain ID for each domain ensures that the routes for each domain remain separate. If a domain ID is not configured, the default value is 0.0.0.0. In addition, if the remote PE router does not advertise a domain ID in the VPN-IPv4 routes, the local PE router assumes the domain ID matches the remote PE routers, and an OSPF Type-3 LSA is issued for the routes. Each VRF table in a PE router associated with an OSPF instance is configured with the same OSPF domain ID.

Whether a route is redistributed and advertised as a Type-3 LSA or as a Type-5 LSA depends on the following:

- If the receiving PE router sees a Type-3 route with a matching domain ID, the route is redistributed and advertised as a Type-3 LSA.
- If the receiving PE router sees a Type-5 route with a matching domain ID, the route is redistributed and advertised as a Type-5 LSA.
- If the receiving PE router sees a Type-3 route without a domain ID, the route is redistributed and advertised as a Type-3 LSA.
- If the receiving PE router sees a Type-3 route with a non-matching domain ID, the route is redistributed and advertised as a Type-5 LSA.
- If the receiving PE router sees a Type-5 route with a non-matching domain ID, the route is redistributed and advertised as a Type-5 LSA.

Figure 22 shows this example's configuration topology. Only the configuration for router PE1 is provided. The configuration for router PE2 can be similar to the configuration for router PE1. There are no special configuration requirements for the CE routers.

Figure 22: Example of a Configuration Using an OSPF Domain ID



Configure Interfaces on Router PE1

You need to configure two interfaces for router PE1—the so-0/0/0 interface for traffic to router CE1 (San Francisco) and the so-0/0/1 interface for traffic to a Provider (P) router in the service provider's network.

Configure the interfaces for router PE1:

```
[edit]
interfaces {
    so-0/0/0 {
        unit 0 {
            family inet {
                address 10.19.1.2/30;
            }
        family mpls;
        }
    }
    so-0/0/1 {
        unit 0 {
            family inet {
                address 10.19.2.1/30;
            }
            family mpls;
        }
    }
}
```

Configure Routing Options on Router PE1

At the [edit routing-options] hierarchy level, you need to configure the router-id and autonomous-system statements. The router-id statement identifies router PE1.

Configure the routing options for router PE1:

```
[edit]
routing-options {
    router-id 10.255.14.216;
    autonomous-system 69;
}
```

Configure Protocols on Router PE1

On router PE1, you need to configure MPLS, BGP, OSPF, and LDP at the [edit protocols] hierarchy level:

```
[edit]
protocols {
    mpls {
        interface so-0/0/0.0;
    }
    bgp {
        group San-Francisco-Chicago {
            type internal;
            preference 10;
            local-address 10.255.14.216;
            family inet-vpn {
                unicast;
            }
            neighbor 10.255.14.224;
        }
    }
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-0/0/1.0;
        }
    }
    ldp {
        interface so-0/0/1.0;
    }
}
```

Configure Policy Options on Router PE1

On router PE1, you need to configure policies at the [edit policy-options] hierarchy level. These policies ensure that the CE routers in the Layer 3 VPN exchange routing information. In this example, router CE1 in San Francisco exchanges routing information with router CE2 in Chicago.

Configure the policy options on the PE1 router:

```
[edit]
policy-options {
    policy-statement vpn-import-VPN-A {
        term term1 {
            from {
                protocol bgp;
                community import-target-VPN-A;
            }
            then accept;
        }
        term term2 {
            then reject;
        }
    }
    policy-statement vpn-export-VPN-A {
        term term1 {
            from protocol ospf;
            then {
                community add export-target-VPN-A;
                accept;
            }
        }
        term term2 {
            then reject;
        }
    }
    community export-target-VPN-B members [ target:10.255.14.216:11 domain-id:1.1.1.1:0 ];
    community import-target-VPN-B members target:10.255.14.224:31;
}
```

Configure the Routing Instance on Router PE1

You need to configure a Layer 3 VPN routing instance on router PE1. To indicate that the routing instance is for a Layer 3 VPN, add the instance-type vrf statement at the [edit routing-instance *routing-instance-name*] hierarchy level.

The domain-id statement is configured at the [edit routing-instances routing-options protocols ospf] hierarchy level. As shown in Figure 22 on page 162, the routing instance on router PE2 must share the same domain ID as the corresponding routing instance on router PE1 so that routes from router CE1 to router CE2 and vice versa are distributed as Type-3 LSAs. If you configure different OSPF domain IDs in the routing instances for router PE1 and router PE2, the routes from each CE router will be distributed as Type-5 LSAs.

Configure the routing instance on router PE1:

```
[edit]
routing-instances {
    VPN-A-San-Francisco-Chicago {
        instance-type vrf;
        interface so-0/0/0.0;
        route-distinguisher 10.255.14.216:11;
        vrf-import vpn-import-VPN-A;
        vrf-export vpn-export-VPN-A;
        routing-options {
            router-id 10.255.14.216;
            autonomous-system 69;
        }
        protocols {
            ospf {
                domain-id 1.1.1.1;
                export vpn-import-VPN-A;
                area 0.0.0.0 {
                    interface so-0/0/0.0;
                }
            }
        }
    }
}
```

Configuration Summary for Router PE1

Configure Interfaces

```
interfaces {
    so-0/0/0 {
        unit 0 {
            family inet {
                address 10.19.1.2/30;
            }
            family mpls;
        }
    }
    so-0/0/1 {
        unit 0 {
            family inet {
                address 10.19.2.1/30;
            }
            family mpls;
        }
    }
}
```

Configure Routing Options

```
routing-options {
    router-id 10.255.14.216;
    autonomous-system 69;
}
```

Configure Protocols

```
protocols {
    mpls {
        interface so-0/0/0.0;
    }
    bgp {
        group San-Francisco-Chicago {
            type internal;
            preference 10;
            local-address 10.255.14.216;
            family inet-vpn {
                unicast;
            }
            neighbor 10.255.14.224;
        }
    }
    ospf {
        traffic-engineering;
        area 0.0.0.0 {
            interface so-0/0/1.0;
        }
    }
    ldp {
        interface so-0/0/1.0;
    }
}
```

Configure VPN Policy

```
policy-options {
    policy-statement vpn-import-VPN-A {
        term term1 {
            from {
                protocol bgp;
                community import-target-VPN-A;
            }
            then accept;
        }
        term term2 {
            then reject;
        }
    }
    policy-statement vpn-export-VPN-A {
        term term1 {
            from protocol ospf;
            then {
                community add export-target-VPN-A;
                accept;
            }
        }
        term term2 {
            then reject;
        }
    }
    community export-target-VPN-B members [ target:10.255.14.216:11 domain-id:1.1.1.1:0 ];
    community import-target-VPN-B members target:10.255.14.224:31;
}
```

Routing Instance for Layer 3 VPN

```
routing-instances {
    VPN-A-San-Francisco-Chicago {
        instance-type vrf;
        interface so-0/0/0.0;
        route-distinguisher 10.255.14.216:11;
        vrf-import vpn-import-VPN-A;
        vrf-export vpn-export-VPN-A;
    routing-options {
        router-id 10.255.14.216;
        autonomous-system 69;
    }
        protocols {
            ospf {
                domain-id 1.1.1.1;
                export vpn-import-VPN-A;
                area 0.0.0.0 {
                    interface so-0/0/0.0;
                }
            }
        }
    }
}
```

Configure Overlapping VPNs Using Routing Table Groups

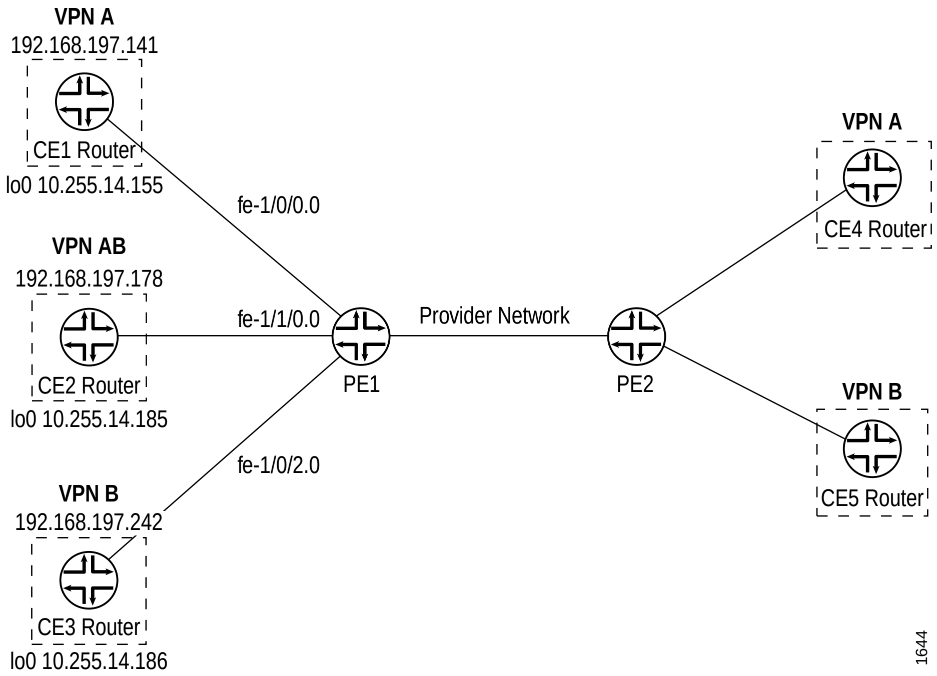
In RFC 2547 Layer 3 VPNs, a CE router is often a member of more than one VPN. This example illustrates how to configure PE routers that support CE routers that support multiple VPNs. Support for this type of configuration uses a JUNOS feature called routing table groups (sometimes also called routing information base [RIB] groups), which allows a route to be installed into several routing tables. A routing table group is a list of routing tables into which the protocol should install its routes.

You define routing table groups at the [edit routing-options] hierarchy level for the default instance. You cannot configure routing table groups at the [routing-instances routing-options] hierarchy level; doing so results in a commit error.

After you define a routing table group, it can be used by multiple protocols. You can also apply routing table groups to static routing. The configuration examples in this section include both types of configurations.

Figure 23 illustrates the topology for the configuration example in this section. The configurations in this section illustrate local connectivity between CE routers connected to the same PE router. If Router PE1 were connected only to Router CE2 (VPN AB), there would be no need for any extra configuration. The configuration statements in the sections that follow enable the VPN AB Router CE2 to communicate with the VPN A Router CE1 and the VPN B Router CE3 that are directly connected to the Router PE1. VPN routes that originate from the remote PE routers (the PE2 router in this case) are placed in a global Layer 3 VPN routing table (bgp.l3vpn.inet.0) and routes with appropriate route targets are imported into the routing tables as dictated by the VRF import policy configuration. The goal is to be able to choose routes from individual VPN routing tables that are locally populated.

Figure 23: Example of an Overlapping VPN Topology



The following sections explain how to configure overlapping VPNs. The last four sections illustrate different scenarios for configuring overlapping VPNs, depending on the routing protocol used between the PE and CE routers.

Router PE1 is where all the filtering and configuration modification takes place. Therefore only VPN configurations for PE1 are shown. The CE routers do not know the VPN exists, so you can configure them normally.

- Configure Routing Table Groups on page 169
- Configure Static Routes between the PE and CE Routers on page 170
- Configure BGP between the PE and CE Routers on page 175
- Configure OSPF between the PE and CE Routers on page 177
- Configure Static, BGP, and OSPF Routes between the PE and CE Routers on page 178

Configure Routing Table Groups

In this example, routing table groups are common in the four configuration scenarios. The routing table groups are used to install routes (including interface, static, OSPF, and BGP routes) into several routing tables for the default and other instances. In the routing table group definition, the first routing table is called the primary routing table. (Normally, the primary routing table is the table into which the route would be installed if you did not configure routing table groups. The other routing tables are called secondary routing tables.)

The routing table groups in this configuration install routes as follows:

- vpna-vpnab installs routes into routing tables VPN-A.inet.0 and VPN-AB.inet.0.
- vpnb-vpnab installs routes into routing tables VPN-B.inet.0 and VPN-AB.inet.0.
- vpnab-vpna_and_vpnb installs routes into routing tables VPN-AB.inet.0, VPN-A.inet.0, and VPN-B.inet.0.

Configure the routing table groups:

```
[edit]
routing-options {
    rib-groups {
        vpna-vpnab {
            import-rib [ VPN-A.inet.0 VPN-AB.inet.0 ];
        }
        vpnb-vpnab {
            import-rib [ VPN-B.inet.0 VPN-AB.inet.0 ];
        }
        vpnab-vpna_and_vpnb {
            import-rib [ VPN-AB.inet.0 VPN-A.inet.0 VPN-B.inet.0 ];
        }
    }
}
```

Configure Static Routes between the PE and CE Routers

To configure static routing between the PE1 router and the CE1, CE2, and CE3 routers, you must configure routing instances for VPN A, VPN B, and VPN AB (you configure static routing under each instance):

- Configure the Routing Instance for VPN A on page 170
- Configure the Routing Instance for VPN AB on page 171
- Configure the Routing Instance for VPN B on page 172
- Configure VPN Policy on page 172

Configure the Routing Instance for VPN A

On Router PE1, configure VPN A:

```
[edit]
routing-instances {
    VPN-A {
        instance-type vrf;
        interface fe-1/0/0.0;
        route-distinguisher 10.255.14.175:3;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            interface-routes {
                rib-group inet vpna-vpnab;
            }
            static {
                route 10.255.14.155/32 next-hop 192.168.197.141;
                route 10.255.14.185/32 next-hop 192.168.197.178;
            }
        }
    }
}
```

The interface-routes statement installs the VPN A’s interface routes into the routing tables defined in the routing table group vpna-vpnab.

The static statement configures the static routes that are installed in the VPN-A.inet.0 routing table. The first static route is for Router CE1 (VPN A) and the second is for Router CE2 (in VPN AB).

Note that next-hop 192.168.197.178 is not in VPN A. Route 10.255.14.185/32 cannot be installed in VPN-A.inet.0 unless interface routes from routing instance VPN AB are installed in this routing table. Including the interface-routes statements in the VPN AB configuration provides this next hop. Similarly, including the interface-routes statement in the VPN AB configuration installs 192.168.197.141 into VPN-AB.inet.0.

Configure the Routing Instance for VPN AB

On Router PE1, configure VPN AB:

```
[edit]
routing instances {
    VPN-AB {
        instance-type vrf;
        interface fe-1/1/0.0;
        route-distinguisher 10.255.14.175:9;
        vrf-import vpnab-import;
        vrf-export vpnab-export;
        routing-options {
            interface-routes {
                rib-group vpnab-vpna_and_vpnb;
            }
            static {
                route 10.255.14.185/32 next-hop 192.168.197.178;
                route 10.255.14.155/32 next-hop 192.168.197.141;
                route 10.255.14.186/32 next-hop 192.168.197.242;
            }
        }
    }
}
```

In this configuration, the following static routes are installed in the VPN-AB.inet.0 routing table:

- 10.255.14.185/32 is for Router CE2 (in VPN AB)
- 10.255.14.155/32 is for Router CE1 (in VPN A)
- 10.255.14.186/32 is for Router CE3 (in VPN B)

192.168.197.141 and 192.168.197.242 do not belong to VPN AB. Routes 10.255.14.155/32 and 10.255.14.186/32 cannot be installed in VPN-AB.inet.0 unless interface routes from VPN A and VPN B are installed in this routing table. The interface route configurations in VPN A and VPN B routing instances provide these next hops.

Configure the Routing Instance for VPN B

On Router PE1, configure VPN B:

```
[edit]
routing instances {
    VPN-B {
        instance-type vrf;
        interface fe-1/0/2.0;
        route-distinguisher 10.255.14.175:10;
        vrf-import vpnb-import;
        vrf-export vpnb-export;
        routing-options {
            interface-routes {
                rib-group inet vpnb-vpnab;
            }
            static {
                route 10.255.14.186/32 next-hop 192.168.197.242;
                route 10.255.14.185/32 next-hop 192.168.197.178;
            }
        }
    }
}
```

When you configure the routing instance for VPN B, these static routes are placed in VPNB.inet.0:

- 10.255.14.186/32 is for Router CE3 (in VPN B)
- 10.255.14.185/32 is for Router CE2 (in VPN AB)

192.168.197.178 does not belong to VPN B. Route 10.255.14.185/32 cannot be installed in VPN-B.inet.0 unless interface routes from VPN AB are installed in this routing table. The interface route configuration in VPN AB provides this next hop.

Configure VPN Policy

The vrf-import and vrf-export policy statements that you configure for overlapping VPNs are the same as policy statements for regular VPNs, except that you include the from interface statement in each VRF export policy. This statement forces each VPN to announce only those routes that originated from that VPN. For example, VPN A has routes that originated in VPN A and VPN AB. If you do not include the from interface statement, VPN A announces its own routes as well as VPN AB's routes, so the remote PE router receives multiple announcements for the same routes. Including the from interface statement restricts each VPN to announcing only the routes it originated and allows you to filter out the routes imported from other routing tables for local connectivity.

In this configuration example, the vpnab-import policy accepts routes from VPN A, VPN B, and VPN AB. The vpna-export policy only exports routes that originate in VPN A. Similarly, the vpnb-export and vpnab-export policies only export routes that originate within the respective VPNs.

On Router PE1, configure the following VPN import and export policies:

```
[edit]
policy-options {
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community VPNA-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpnb-import {
        term a {
            from {
                protocol bgp;
                community VPNB-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpnab-import {
        term a {
            from {
                protocol bgp;
                community [ VPNA-comm VPNB-comm ];
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-export {
        term a {
            from {
                protocol static;
                interface fe-1/0/0.0;
            }
            then {
                community add VPNA-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
```

```
        policy-statement vpnb-export {
            term a {
                from {
                    protocol static;
                    interface fe-1/0/2.0;
                }
                then {
                    community add VPNB-comm;
                    accept;
                }
            }
            term b {
                then reject;
            }
        }
        policy-statement vpnab-export {
            term a {
                from {
                    protocol static;
                    interface fe-1/1/0.0;
                }
                then {
                    community add VPNB-comm;
                    community add VPNA-comm;
                    accept;
                }
            }
            term b {
                then reject;
            }
        }
        community VPNA-comm members target:69:1;
        community VPNB-comm members target:69:2;
    }
```

On Router PE1, apply the VPN import and export policies.

```
[edit]
routing-instances {
    VPN-A {
        instance-type vrf;
        interface fe-1/0/0.0;
        route-distinguisher 10.255.14.175:3;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                rib-group vpna-vpnab;
                route 10.255.14.155/32 next-hop 192.168.197.141;
            }
        }
    }
```

```
        VPN-AB {
            instance-type vrf;
            interface fe-1/1/0.0;
            route-distinguisher 10.255.14.175:9;
            vrf-import vpnab-import;
            vrf-export vpnab-export;
            routing-options {
                static {
                    rib-group vpnab-vpna_and_vpnb;
                    route 10.255.14.185/32 next-hop 192.168.197.178;
                }
            }
        }
        VPN-B {
            instance-type vrf;
            interface fe-1/0/2.0;
            route-distinguisher 10.255.14.175:10;
            vrf-import vpnb-import;
            vrf-export vpnb-export;
            routing-options {
                static {
                    rib-group vpnb-vpnab;
                    route 10.255.14.186/32 next-hop 192.168.197.242;
                }
            }
        }
    }
```

For VPN A, include the routing-options statement at the [edit routing-instances *routing-instance-name*] hierarchy level to install the static route directly into the routing tables defined in the routing table group vpna-vpnab. For VPN AB, the configuration installs the static route directly into the routing tables defined in the routing table group vpnab-vpna and vpnab-vpnb. For VPN B the configuration installs the static route directly into the routing tables defined in the routing table group vpnb-vpnab.

Configure BGP between the PE and CE Routers

In this configuration example, the vpna-site1 BGP group for VPN A installs the routes learned from the BGP session into the routing tables defined in the vpna-vpnab routing table group. For VPN AB, the vpnab-site1 group installs the routes learned from the BGP session into the routing tables defined in the vpnab-vpna_and_vpnb routing table group. For VPN B, the vpnb-site1 group installs the routes learned from the BGP session into the routing tables defined in the vpnb-vpnab routing table group. Note that interface routes are not needed for this configuration.

The VRF import and export policies are similar to those defined in “Configure Static Routes between the PE and CE Routers” on page 170, except the export protocol is BGP instead of a static route. On all vrf-export policies, you use the from protocol bgp statement.

On Router PE1, configure BGP between the PE and CE routers:

```
[edit]
routing-instances {
    VPN-A {
        instance-type vrf;
        interface fe-1/0/0.0;
        route-distinguisher 10.255.14.175:3;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            bgp {
                group vpna-site1 {
                    family inet {
                        unicast {
                            rib-group vpna-vpnab;
                        }
                    }
                    peer-as 1;
                    neighbor 192.168.197.141;
                }
            }
        }
    }
    VPN-AB {
        instance-type vrf;
        interface fe-1/1/0.0;
        route-distinguisher 10.255.14.175:9;
        vrf-import vpnab-import;
        vrf-export vpnab-export;
        protocols {
            bgp {
                group vpnab-site1 {
                    family inet {
                        unicast {
                            rib-group vpnab-vpna_and_vpnb;
                        }
                    }
                    peer-as 9;
                    neighbor 192.168.197.178;
                }
            }
        }
    }
    VPN-B {
        instance-type vrf;
        interface fe-1/0/2.0;
        route-distinguisher 10.255.14.175:10;
        vrf-import vpnb-import;
        vrf-export vpnb-export;
        protocols {
            bgp {
                group vpnb-site1 {
                    family inet {
                        unicast {
                            rib-group vpnb-vpnab;
                        }
                    }
                    neighbor 192.168.197.242 {
                        peer-as 10;
                    }
                }
            }
        }
    }
}
```

Configure OSPF between the PE and CE Routers

In this configuration example, routes learned from the OSPF session for VPN A are installed into the routing tables defined in the vpna-vpnab routing table group. For VPN AB, routes learned from the OSPF session are installed into the routing tables defined in the vpnab-vpna_and_vpnb routing table group. For VPN B, routes learned from the OSPF session are installed into the routing tables defined in the vpnb-vpnab routing table group.

The VRF import and export policies are similar to those defined in “Configure Static Routes between the PE and CE Routers” on page 170 and “Configure BGP between the PE and CE Routers” on page 175, except the export protocol is OSPF instead of BGP or a static route. Therefore, on all vrf-export policies, you use the from protocol <static | bgp> statement instead of the from protocol ospf statement.

On Router PE1, configure OSPF between the PE and CE routers:

```
[edit]
routing-instances {
    VPN-A {
        instance-type vrf;
        interface fe-1/0/0.0;
        route-distinguisher 10.255.14.175:3;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            ospf {
                rib-group vpna-vpnab;
                export vpna-import;
                area 0.0.0.0 {
                    interface fe-1/0/0.0;
                }
            }
        }
    }
    VPN-AB {
        instance-type vrf;
        interface fe-1/1/0.0;
        route-distinguisher 10.255.14.175:9;
        vrf-import vpnab-import;
        vrf-export vpnab-export;
        protocols {
            ospf {
                rib-group vpnab-vpna_and_vpnb;
                export vpnab-import;
                area 0.0.0.0 {
                    interface fe-1/1/0.0;
                }
            }
        }
    }
    VPN-B {
        instance-type vrf;
        interface fe-1/0/2.0;
        route-distinguisher 10.255.14.175:10;
        vrf-import vpnb-import;
        vrf-export vpnb-export;
        protocols {
            ospf {
                rib-group vpnb-vpnab;
                export vpnb-import;
                area 0.0.0.0 {
                    interface fe-1/0/2.0;
                }
            }
        }
    }
}
```

Configure Static, BGP, and OSPF Routes between the PE and CE Routers

This section shows how to configure the routes between the PE and CE routers using a combination of static routes, BGP, and OSPF, as follows:

- The connection between Router PE1 and Router CE1 uses static routing.
- The connection between Router PE1 and Router CE2 uses BGP.
- The connection between Router PE1 and Router CE3 uses OSPF.

Here, the configuration for VPN AB also includes a static route to CE1.

On Router PE1, configure a combination of static routing, BGP, and OSPF between the PE and CE routers:

```
[edit]
routing-instances {
    VPN-A {
        instance-type vrf;
        interface fe-1/0/0.0;
        route-distinguisher 10.255.14.175:3;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                rib-group vpna-vpnab;
                route 10.255.14.155/32 next-hop 192.168.197.141;
            }
        }
    }
    VPN-AB {
        instance-type vrf;
        interface fe-1/1/0.0;
        route-distinguisher 10.255.14.175:9;
        vrf-import vpnab-import;
        vrf-export vpnab-export;
        protocols {
            bgp {
                group vpnab-site1 {
                    family inet {
                        unicast {
                            rib-group vpnab-vpna_and_vpnb;
                        }
                    }
                    export to-vpnab-site1;
                    peer-as 9;
                    neighbor 192.168.197.178;
                }
            }
        }
    }
    VPN-B {
        instance-type vrf;
        interface fe-1/0/2.0;
        route-distinguisher 10.255.14.175:10;
        vrf-import vpnb-import;
        vrf-export vpnb-export;
        protocols {
            ospf {
                rib-group vpnb-vpnab;
                export vpnb-import;
                area 0.0.0.1 {
                    interface t3-0/3/3.0;
                }
            }
        }
    }
}
policy-options {
    policy-statement to-vpnab-site1 {
        term a {
            from protocol static;
            then accept;
        }
        term b {
            from protocol bgp;
            then accept;
        }
        term c {
            then reject;
        }
    }
}
```

Configuring Overlapping VPNs Using auto-export

A problem with multiple routing instances is how to export routes between routing instances. This can be accomplished in JUNOS by configuring routing table groups for each routing instance that needs to export routes to other routing tables. For information on how to configure overlapping VPNs using routing table groups, see "Configure Overlapping VPNs Using Routing Table Groups" on page 168.

However, using routing table groups has limitations:

- Routing table group configuration is complex. A unique routing table group must be defined for each routing instance that will export routes.
- You must also configure a unique routing table group for each protocol that will export routes.

To limit and sometimes eliminate the need to configure routing table groups in multiple routing instance topologies, you can use the functionality provided by the auto-export statement.

The auto-export statement is particularly useful for configuring overlapping VPNs—VPN configurations where more than one VRF lists the same community route target in its vrf-import policy. The auto-export statement finds out which routing tables to export routes from and import routes to by examining the existing policy configuration.

The auto-export statement automatically exports routes between the routing instances referencing a given route target community. When the auto-export statement is configured, a VRF target tree is constructed based on the vrf-import and vrf-export policies configured on the system. If a routing instance references a target in its vrf-import policy, it is added to the import list for the target. If it references a specific route target in its vrf-export policy, it is added to the export list for that target. Route targets where there is a single importer that matches a single exporter or with no importers or exporters are ignored.

Changes to routing tables that export route targets are tracked. When a route change occurs, the routing instance's vpn-export policy is applied to the route. If it is allowed, the route is imported to all the import tables (subject to the vrf-import policy) of the route targets set by the export policy.

The sections that follow describe how to configure overlapping VPNs using the auto-export statement for interinstance export in addition to routing table groups:

- "Configuring Overlapping VPNs with BGP and auto-export" on page 181
- "Configuring Overlapping VPNs and Additional Tables" on page 182
- "Configuring auto-export for all VRF Instances" on page 183

Configuring Overlapping VPNs with BGP and auto-export

The following example provides the configuration for an overlapping VPN where BGP is used between the PE and CE routers:

Configure routing instance VPN-A as follows:

```
[edit]
routing-instances {
    VPN-A {
        instance-type vrf;
        interface fe-1/0/0.0;
        route-distinguisher 10.255.14.175:3;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            auto-export;
        }
        protocols {
            bgp {
                group vpna-site1 {
                peer-as 1;
                neighbor 192.168.197.141;
            }
        }
    }
}
```

Configure routing instance VPN-AB as follows:

```
[edit]
routing-instances {
    VPN-AB {
        instance-type vrf;
        interface fe-1/1/0.0;
        route-distinguisher 10.255.14.175:9;
        vrf-import vpnab-import;
        vrf-export vpnab-export;
        routing-options {
            auto-export;
        }
        protocols {
            bgp {
                group vpnab-site1 {
                    peer-as 9;
                    neighbor 192.168.197.178;
                }
            }
        }
    }
}
```

For this configuration, the auto-export statement replaces the functionality that was provided by a routing table group configuration. However, sometimes additional configuration is required.

Since the vrf-import policy and the vrf-export policy from which the auto-export statement deduces the import and export matrix are configured on a per-instance basis, it is necessary to be able to enable or disable them for unicast and multicast, in case a multicast NLRI is configured.

Configuring Overlapping VPNs and Additional Tables

It might be necessary to use the auto-export statement between overlapping VPNs, but require that a subset of the routes learned from a VRF table be installed into the inet.0 table or in routing-instance.inet.2.

To support this type of scenario, where not all of the information needed is present in the vrf-import and vrf-export policies, you configure an additional list of routing tables using an additional routing table group.

To add routes from VPN-A and VPN-AB to inet.0 in the example described in "Configuring Overlapping VPNs with BGP and auto-export" on page 181, you need to include the following additional configuration statements:

Configure the routing options as follows:

```
[edit]
routing-options {
    rib-groups {
        inet-access {
            import-rib inet.0;
        }
    }
}
```

Configure routing instance VPN-A as follows:

```
[edit]
routing-instances {
    VPN-A {
    routing-options {
        auto-export {
            family inet {
                unicast {
                    rib-group inet-access;
                }
            }
        }
    }
}
```

Configure routing instance VPN-AB as follows:

```
[edit]
routing-instances {
    VPN-AB {
    routing-options {
        auto-export {
            family inet {
                unicast {
                    rib-group inet-access;
                }
            }
        }
    }
}
```

Routing table groups are used in this configuration differently from how they are generally used in JUNOS. Routing table groups normally require that the exporting routing table be referenced as the primary import routing table in the routing table group. For this configuration, the restriction does not apply. The routing table group functions as an additional list of tables to export routes to.

Configuring auto-export for all VRF Instances

The following configuration allows you to configure the auto-export statement for all of the routing instances in a configuration group:

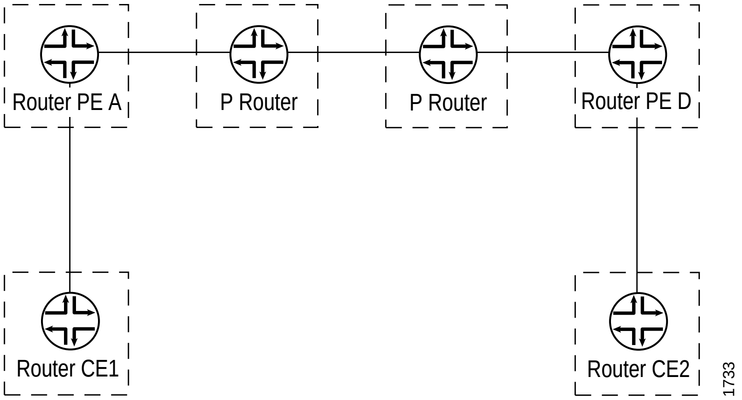
```
[edit]
groups {
    vrf-export-on {
        routing-instances {
            <*> {
                routing-options {
                    auto-export;
                }
            }
        }
    }
}

apply-groups vrf-export-on;
```

Configure a GRE Tunnel Interface between PE Routers

This example shows how to configure a generic routing encapsulation (GRE) tunnel interface between provider edge (PE) routers to provide VPN connectivity. You can use this configuration to tunnel VPN traffic across a non-MPLS core network. The network topology used in this example is shown in Figure 24. Note that the provider (P) routers shown in this illustration do not run MPLS.

Figure 24: PE Router A and PE Router D Connected by a GRE Tunnel Interface



Configure the Routing Instance on Router A

Configure a routing instance on Router A as follows:

```
[edit routing-instances]
gre-config {
    instance-type vrf;
    interface fe-1/0/0.0;
    route-distinguisher 10.255.14.176:69;
    vrf-import import-config;
    vrf-export export-config;
    protocols {
        ospf {
            export import-config;
            area 0.0.0.0 {
                interface all;
            }
        }
    }
}
```

Configure the Routing Instance on Router D

Configure a routing instance on Router D as follows:

```
[edit routing-instances]
gre-config {
    instance-type vrf;
    interface fe-1/0/1.0;
    route-distinguisher 10.255.14.178:69;
    vrf-import import-config;
    vrf-export export-config;
    protocols {
        ospf {
            export import-config;
            area 0.0.0.0 {
                interface all;
            }
        }
    }
}
```

Configure MPLS, BGP, and OSPF on Router A

Though MPLS does not need to be configured on the P routers in this example, it is needed on the PE routers for the interface between the PE and CE routers and on the GRE interface (gr-1/1/0.0) linking the PE routers (Router A and Router D). Configure MPLS, BGP, and OSPF on Router A as follows:

```
[edit protocols]
mpls {
    interface all;
}
bgp {
    group pe-to-pe {
        type internal;
        neighbor 10.255.14.178 {
            family inet-vpn {
                unicast;
            }
        }
    }
}
ospf {
    area 0.0.0.0 {
        interface all;
        interface gr-1/1/0.0 {
            disable;
        }
    }
}
```

Configure MPLS, BGP, and OSPF on Router D

Though MPLS does not need to be configured on the P routers in this example, it is needed on the PE routers for the interface between the PE and CE routers and on the GRE interface (gr-1/1/0.0) linking the PE routers (Router D and Router A). Configure MPLS, BGP, and OSPF on Router D as follows:

```
[edit protocols]
mpls {
    interface all;
}
bgp {
    group pe-to-pe {
        type internal;
        neighbor 10.255.14.176 {
            family inet-vpn {
                unicast;
            }
        }
    }
}
ospf {
    traffic-engineering;
    area 0.0.0.0 {
        interface all;
        interface fxp0.0 {
            disable;
        }
        interface gr-1/1/0.0 {
            disable;
        }
    }
}
```

Configure the Tunnel Interface on Router A

Configure the tunnel interface on Router A as follows (note that the tunnel is unnumbered):

```
[edit interfaces interface-name]
unit 0 {
    tunnel {
        source 10.255.14.176;
        destination 10.255.14.178;
    }
    family inet;
    family mpls;
}
```

Configure the Tunnel Interface on Router D

Configure the tunnel interface on Router D as follows (note that the tunnel is unnumbered):

```
[edit interfaces interface-name]
unit 0 {
    tunnel {
        source 10.255.14.178;
        destination 10.255.14.176;
    }
    family inet;
    family mpls;
}
```

Configure the Routing Options on Router A

As part of the routing options configuration for Router A, you need to configure routing table groups to enable VPN route resolution in the inet.3 routing table.

Configure the routing options on Router A as follows:

```
[edit routing-options]
interface-routes {
    rib-group inet if-rib;
}
rib inet.3 {
    static {
        route 10.255.14.178/32 next-hop gr-1/1/0.0;
    }
}
rib-groups {
    if-rib {
        import-rib [ inet.0 inet.3 ];
    }
}
```

Configure the Routing Options on Router D

As part of the routing options configuration for Router D, you need to configure routing table groups to enable VPN route resolution in the inet.3 routing table.

Configure the routing options on Router D as follows:

```
[edit routing-options]
interface-routes {
    rib-group inet if-rib;
}
rib inet.3 {
    static {
        route 10.255.14.176/32 next-hop gr-1/1/0.0;
    }
}
rib-groups {
    if-rib {
        import-rib [ inet.0 inet.3 ];
    }
}
```

Configuration Summary for Router A

Configure the Routing Instance

```
gre-config {
    instance-type vrf;
    interface fe-1/0/0.0;
    route-distinguisher 10.255.14.176:69;
    vrf-import import-config;
    vrf-export export-config;
    protocols {
        ospf {
            export import-config;
            area 0.0.0.0 {
                interface all;
            }
        }
    }
}
```

Configure MPLS

```
mpls {
    interface all;
}
```

Configure BGP

```
bgp {
    traceoptions {
        file bgp.trace world-readable;
        flag update detail;
    }
    group pe-to-pe {
        type internal;
        neighbor 10.255.14.178 {
            family inet-vpn {
                unicast;
            }
        }
    }
}
```

Configure OSPF

```
ospf {
    area 0.0.0.0 {
        interface all;
        interface gr-1/1/0.0 {
            disable;
        }
    }
}
```

Configure the Tunnel Interface

```
interface-name {
    unit 0 {
        tunnel {
            source 10.255.14.176;
            destination 10.255.14.178;
        }
        family inet;
    }
}
```

Configure Routing Options

```
interface-routes {
    rib-group inet if-rib;
}
rib inet.3 {
    static {
        route 10.255.14.178/32 next-hop gr-1/1/0.0;
    }
}
rib-groups {
    if-rib {
        import-rib [ inet.0 inet.3 ];
    }
}
```

Configuration Summary for Router D

Configure the Routing Instance

```
gre-config {
    instance-type vrf;
    interface fe-1/0/1.0;
    route-distinguisher 10.255.14.178:69;
    vrf-import import-config;
    vrf-export export-config;
    protocols {
        ospf {
            export import-config;
            area 0.0.0.0 {
                interface all;
            }
        }
    }
}
```

Configure MPLS

```
mpls {
    interface all;
}
```

Configure BGP

```
bgp {
    group pe-to-pe {
        type internal;
        neighbor 10.255.14.176 {
            family inet-vpn {
                unicast;
            }
        }
    }
}
```

Configure OSPF

```
ospf {
    traffic-engineering;
    area 0.0.0.0 {
        interface all;
        interface fxp0.0 {
            disable;
        }
        interface gr-1/1/0.0 {
            disable;
        }
    }
}
```

Configure the Tunnel Interface

```
interface-name {
    unit 0 {
        tunnel {
            source 10.255.14.178;
            destination 10.255.14.176;
        }
        family inet;
    }
}
```

Configure the Routing Options

```
interface-routes {
    rib-group inet if-rib;
}
rib inet.3 {
    static {
        route 10.255.14.176/32 next-hop gr-1/1/0.0;
    }
}
rib-groups {
    if-rib {
        import-rib [ inet.0 inet.3 ];
    }
}
```

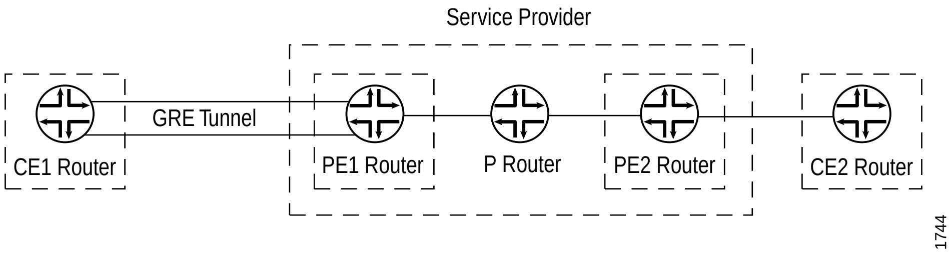
Configure a GRE Tunnel Interface between a PE and CE Router

This example shows how to configure a generic routing encapsulation (GRE) tunnel interface between a provider edge (PE) router and a custom edge (CE) router. You can use this configuration to tunnel VPN traffic across a non-MPLS core network. The network topology used in this example is shown in Figure 25.

For this example, complete the procedures described in the following sections:

- Configure the Routing Instance without the Encapsulating Interface on page 191
- Configure the Routing Instance with the Encapsulating Interface on page 192
- Configure the GRE Tunnel Interface on Router CE1 on page 193

Figure 25: GRE Tunnel between the CE Router and the PE Router



Configure the Routing Instance without the Encapsulating Interface

You can configure the routing instance either with or without the encapsulating interface. The sections that follow describe how to configure the routing instance without it:

- Configure the Routing Instance on Router PE1 on page 191
- Configure the GRE Tunnel Interface on Router PE1 on page 191
- Configure the Encapsulation Interface on Router PE1 on page 192

Configure the Routing Instance on Router PE1

Configure the routing instance on router PE1 as follows:

```
[edit routing-instances]
vpna {
    instance-type vrf;
    interface gr-1/2/0.0;
    route-distinguisher 10.255.14.174:1;
    vrf-import vpna-import;
    vrf-export vpna-export;
    protocols {
        bgp {
            group vpna {
                type external;
                peer-as 100;
                as-override;
                neighbor 10.49.2.1;
            }
        }
    }
}
```

Configure the GRE Tunnel Interface on Router PE1

Configure the GRE tunnel interface on router PE1 as follows:

```
[edit interfaces gr-1/2/0]
unit 0 {
    tunnel {
        source 192.168.197.249;
        destination 192.168.197.250;
    }
    family inet {
        address 10.49.2.2/30;
    }
    family mpls;
}
```

In this example, interface t3-0/1/3 acts as the encapsulating interface for the GRE tunnel.

Configure the Encapsulation Interface on Router PE1

Configure the encapsulation interface on router PE1 as follows:

```
[edit interfaces t3-0/1/3]
unit 0 {
    family inet {
        address 192.168.197.249/30;
    }
    family mpls;
}
```

Configure the Routing Instance with the Encapsulating Interface

If the tunnel encapsulating interface, t3-0/1/3, is also configured under the routing instance, then you need to specify the name of that routing instance under the interface definition. The system uses this routing instance to search for the tunnel destination address.

To configure the routing instance with the encapsulating interface, complete the procedures described in the sections that follow:

- Configure the Routing Instance on Router PE1 on page 192
- Configure the GRE Tunnel Interface on Router PE1 on page 193
- Configure the Encapsulation Interface on Router PE1 on page 193

Configure the Routing Instance on Router PE1

If you configure the tunnel encapsulating interface under the routing instance, then configure the routing instance on router PE1 as follows:

```
[edit routing-instances]
vpna {
    instance-type vrf;
    interface gr-1/2/0.0;
    interface t3-0/1/3.0;
    route-distinguisher 10.255.14.174:1;
    vrf-import vpna-import;
    vrf-export vpna-export;
    protocols {
        bgp {
            group vpna {
                type external;
                peer-as 100;
                as-override;
                neighbor 10.49.2.1;
            }
        }
    }
}
```

Configure the GRE Tunnel Interface on Router PE1

Configure the GRE tunnel interface on router PE1 as follows:

```
[edit interfaces gr-1/2/0]
unit 0 {
    tunnel {
        source 192.168.197.249;
        destination 192.168.197.250;
        routing-instance {
            destination vpna;
        }
    }
    family inet {
        address 10.49.2.2/30;
    }
    family mpls;
}
```

Configure the Encapsulation Interface on Router PE1

Configure the encapsulation interface on router PE1 as follows:

```
[edit interfaces t3-0/1/3]
unit 0 {
    family inet {
        address 192.168.197.249/30;
    }
    family mpls;
}
```

Configure the GRE Tunnel Interface on Router CE1

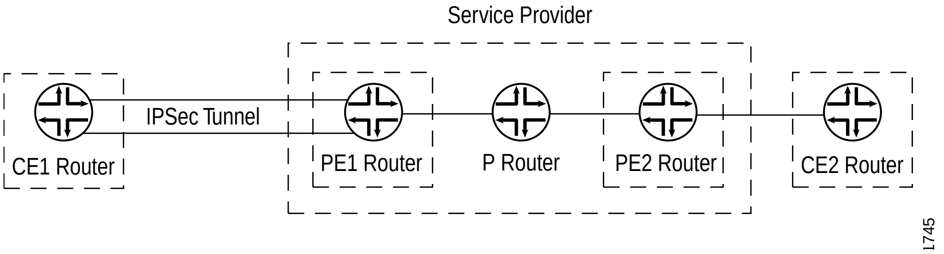
Configure the GRE tunnel interface on router CE1 as follows:

```
[edit interfaces gr-1/2/0]
unit 0 {
    tunnel {
        source 192.168.197.250;
        destination 192.168.197.249;
    }
    family inet {
        address 10.49.2.1/30;
    }
 }
```

Configure an ES Tunnel Interface between a PE and CE Router

This example shows how to configure an ES tunnel interface between a provider edge (PE) router and a CE router in a Layer 3 VPN. The network topology used in this example is shown in Figure 26.

Figure 26: ES Tunnel Interface (IPSec Tunnel) between the CE router and the PE router



To configure this example, complete the steps outlined in the following sections:

- Configure IPSec on Router PE1 on page 194
- Configure the Routing Instance without the Encapsulating Interface on page 195
- Configure the Routing Instance with the Encapsulating Interface on page 196
- Configure the ES Tunnel Interface on Router CE1 on page 197
- Configure IPSec on Router CE1 on page 198

Configure IPSec on Router PE1

Configure IPSec on router PE1 as follows:

```
[edit security]
ipsec {
    security-association sa-esp-manual {
        mode tunnel;
        manual {
            direction bidirectional {
                protocol esp;
                spi 45000;
                authentication {
                    algorithm hmac-md5-96;
                    key ascii-text "$9$ABULt1heK87dsWLDk.P3nrevM7V24ZHkPaZ/tp0cSvWLNwgZUH";
                }
                encryption {
                    algorithm des-cbc;
                    key ascii-text "$9$/H8Q90IyrvL7VKMZjHqQzcyleLN";
                }
            }
        }
    }
}
```

Configure the Routing Instance without the Encapsulating Interface

You can configure the routing instance on router PE1 with or without the encapsulating interface (t3-0/1/3 in this example). The following sections describes how to configure the routing instance without it:

- Configure the Routing Instance on Router PE1 on page 195
- Configure the ES Tunnel Interface on Router PE1 on page 195
- Configure the Encapsulating Interface for the ES Tunnel on Router PE1 on page 196

Configure the Routing Instance on Router PE1

Configure the routing instance on router PE1 as follows:

```
[edit routing-instances]
vpna {
    instance-type vrf;
    interface es-1/2/0.0;
    route-distinguisher 10.255.14.174:1;
    vrf-import vpna-import;
    vrf-export vpna-export;
    protocols {
        bgp {
            group vpna {
                type external;
                peer-as 100;
                as-override;
                neighbor 10.49.2.1;
            }
        }
    }
}
```

Configure the ES Tunnel Interface on Router PE1

Configure the ES tunnel interface on router PE1 as follows:

```
[edit interfaces es-1/2/0]
unit 0 {
    tunnel {
        source 192.168.197.249;
        destination 192.168.197.250;
    }
    family inet {
        address 10.49.2.2/30;
        ipsec-sa sa-esp-manual;
    }
    family mpls;
}
```

Configure the Encapsulating Interface for the ES Tunnel on Router PE1

For this example, interface t3-0/1/3 is the encapsulating interface for the ES tunnel. Configure interface t3-0/1/3 as follows:

```
[edit interfaces t3-0/1/3]
unit 0 {
    family inet {
        address 192.168.197.249/30;
    }
    family mpls;
}
```

Configure the Routing Instance with the Encapsulating Interface

If the tunnel encapsulating interface, t3-0/1/3, is also configured under the routing instance, you need to specify the routing instance name under the interface definition. The system uses this routing instance to search for the tunnel destination address for the IPSec tunnel using manual security association.

The following sections describe how to configure the routing instance with the encapsulating interface:

- Configure the Routing Instance on Router PE1 on page 196
- Configure the ES Tunnel Interface on Router PE1 on page 197
- Configure the Encapsulating Interface on Router PE1 on page 197

Configure the Routing Instance on Router PE1

Configure the routing instance on router PE1 (including the tunnel encapsulating interface) as follows:

```
[edit routing-instances]
vpna {
    instance-type vrf;
    interface es-1/2/0.0;
    interface t3-0/1/3.0;
    route-distinguisher 10.255.14.174:1;
    vrf-import vpna-import;
    vrf-export vpna-export;
    protocols {
        bgp {
            group vpna {
                type external;
                peer-as 100;
                as-override;
                neighbor 10.49.2.1;
            }
        }
    }
}
```

Configure the ES Tunnel Interface on Router PE1

Configure the ES tunnel interface on router PE1 as follows:

```
[edit interfaces es-1/2/0]
unit 0 {
    tunnel {
        source 192.168.197.249;
        destination 192.168.197.250;
        routing-instance {
            destination vpna;
        }
    }
    family inet {
        address 10.49.2.2/30;
        ipsec-sa sa-esp-manual;
    }
    family mpls;
}
```

Configure the Encapsulating Interface on Router PE1

Configure the encapsulating interface on router PE1 as follows:

```
[edit interfaces t3-0/1/3]
unit 0 {
    family inet {
        address 192.168.197.249/30;
    }
    family mpls;
}
```

Configure the ES Tunnel Interface on Router CE1

Configure the ES tunnel interface on router CE1 as follows:

```
[edit interfaces es-1/2/0]
unit 0 {
    tunnel {
        source 192.168.197.250;
        destination 192.168.197.249;
    }
    family inet {
        address 10.49.2.1/30;
        ipsec-sa sa-esp-manual;
    }
}
```

Configure IPSec on Router CE1

Configure IPSec on router CE1 as follows:

```
[edit security]
ipsec {
    security-association sa-esp-manual {
        mode tunnel;
        manual {
            direction bidirectional {
                protocol esp;
                spi 45000;
                authentication {
                    algorithm hmac-md5-96;
                    key ascii-text "$9$ABULt1heK87dsWLDk.P3nrevM7V24ZHkPaZ/tp0cSvWLNwgZUH";
                }
                encryption {
                    algorithm des-cbc;
                    key ascii-text "$9$/H8Q90IyrvL7VKMZjHqQzcyleLN";
                }
            }
        }
    }
```

Configure SCU and DCU for Layer 3 VPNs

For information on how to configure source class usage (SCU) for a Layer 3 VPN loopback interface, see the *JUNOS Internet Software Configuration Guide: Network Management*.

For information on how to configure SCU and destination class usage (DCU) to count packets on Layer 3 VPNs, see the *JUNOS Internet Software Configuration Guide: Interfaces and Class of Service*.

Chapter 10
Layer 3 VPN Internet Access Examples

JUNOS software supports Internet access from a Layer 3 virtual private network (VPN). This chapter provides examples that demonstrate how to configure a provider edge (PE) router to provide Internet access to customer edge (CE) routers in a VPN. The method you use depends on the needs and specifications of the individual network. To provide Internet access through a Layer 3 VPN, you need to configure policies on the PE router. You also need to configure the next-table keyword at the [edit routing-instances *routing-instance-name* routing-options static route] hierarchy level. When configured, this statement can point a default route from the VPN table (routing instance) to the main routing table (default instance) inet.0. The main routing table stores all Internet routes and is where final route resolution occurs.

There are several ways to configure a PE router to provide CE routers access to the Internet. These types of access are described in the following sections:

- Non-VRF Internet Access on page 199—Internet and VPN access are separate. The CE routers access the Internet independently of the PE routers.
- Distributed Internet Access on page 200—The PE router provides Internet access to the CE routers. Internet route information is stored in the PE router's main routing table.
- Centralized Internet Access on page 225—Some of the CE routers are specially configured to provide Internet access to the other CE routers within the VPN.

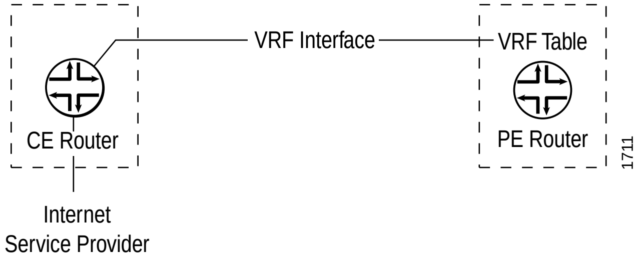
Non-VRF Internet Access

The following sections describe ways to provide Internet access to a CE router in a Layer 3 VPN without using the Virtual Routing and Forwarding (VRF) interface. Because these methods effectively bypass the Layer 3 VPN, they are not discussed in detail.

CE Router Accesses Internet Independently of the PE Router

In this configuration, the PE router does not provide the Internet access. The CE router sends Internet traffic either to another service provider, or to the same service provider but a different router. The PE router handles Layer 3 VPN traffic only (see Figure 27).

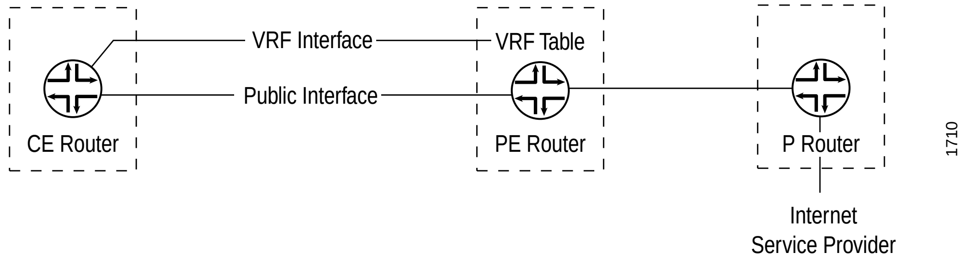
Figure 27: PE Router Does Not Provide Internet Access



PE Router Provides Layer 2 Internet Service

In this configuration, the PE router acts as a Layer 2 device, providing a Layer 2 connection (such as circuit cross-connect [CCC]) to another router that has a full set of Internet routes. The CE router can use just one physical interface and two logical interfaces to the PE router, or it can use multiple physical interfaces to the PE router (see Figure 28).

Figure 28: PE Router Connects to a Router Connected to the Internet



Distributed Internet Access

In this scenario, the PE routers provide Internet access to the CE routers. In the examples that follow, it is assumed that the Internet routes (or defaults) are present in the inet.0 table of the PE routers that provide Internet access to selected CE routers.

When accessing the Internet from a VPN, Network Address Translation (NAT) must be performed between the VPN's private addresses and the public addresses used on the Internet unless the VPN is using the public address space. This section includes several examples of how to provide Internet access for VPNs, most of which require that the CE routers perform the address translation. The "Route Internet Traffic through a Separate NAT Device" example, however, requires that the service provider supply the NAT functionality using a NAT device connected to the PE router.

This section includes the following examples:

- Route VPN and Internet Traffic through Different Interfaces
- Route VPN and Outgoing Internet Traffic through the Same Interface and Route Return Internet Traffic through a Different Interface

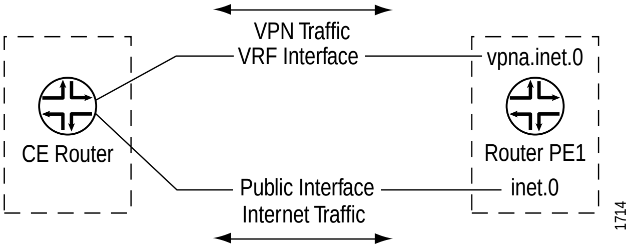
- Route VPN and Internet Traffic through the Same Interface Bidirectionally (VPN Has Public Addresses)
- Route VPN and Internet Traffic through the Same Interface Bidirectionally (VPN Has Private Addresses)
- Route Internet Traffic through a Separate NAT Device

In all the examples, the VPN's public IP address pool (whose entries correspond to the translated private addresses) must be added to the inet.0 table and propagated to the Internet routers to receive reverse traffic from public destinations.

Route VPN and Internet Traffic through Different Interfaces

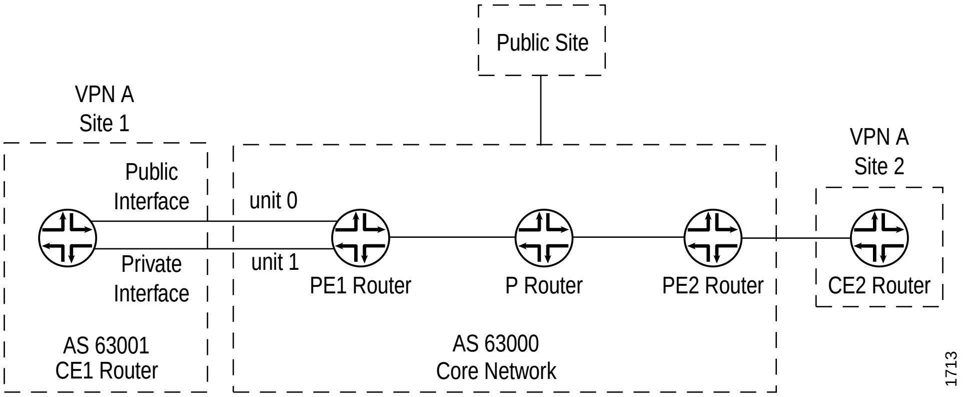
In this example, VPN and Internet traffic are routed through different interfaces. The CE router sends the VPN traffic through the VPN interface and sends the Internet traffic through a separate interface that is part of the main routing table on router PE1 (the CE router can use either one physical interface with two logical units or two physical interfaces). NAT also occurs on the CE router (see Figure 29).

Figure 29: Routing VPN and Internet Traffic through Different Interfaces



The PE router is configured to install and advertise the public IP address pool for the VPN to other core routers (for return traffic). The VPN traffic is routed normally. Figure 30 illustrates the PE router's VPN configuration.

Figure 30: Example of Internet Traffic Routed through Separate Interfaces



The configuration in this example has the following features:

- Router PE1 uses two logical interfaces to connect to router CE1 using Frame Relay encapsulation.
- The routing protocol between router PE1 and router CE1 is External Border Gateway Protocol (EBGP).
- Router CE1's public IP address pool is 10.12.1.1-10.12.1.254 (10.12.1.0/24).
- The next-hop-self setting is derived from the fix-nh policy statement on router PE1. PE routers are forced to use next-hop-self so that next-hop resolution is done only for the PE router's loopback address for non-VPN routes (by default, VPN IPv4 routes are sent using next-hop-self).

You can configure router CE1 with a static default route pointing to its public interface for everything else.

Configure Interfaces on Router PE1

Configure an interface to handle VPN traffic and an interface to handle Internet traffic:

```
[edit]
interfaces {
    t3-0/2/0 {
        dce;
        encapsulation frame-relay;
        unit 0 {
            description "to CE1 VPN interface";
            dlci 10;
            family inet {
                address 192.168.197.13/30;
            }
        }
        unit 1 {
            description "to CE1 public interface";
            dlci 20;
            family inet {
                address 192.168.198.201/30;
            }
        }
    }
}
```

Configure Routing Options on Router PE1

Configure a static route on router PE1 to install a route to the CE router's public IP address pool in inet.0:

```
[edit]
routing-options {
    static {
        route 10.12.1.0/24 next-hop 192.168.198.202;
    }
}
```

Configure BGP, ISIS, and LDP Protocols on Router PE1

Configure BGP on router PE1 to allow non-VPN and VPN peering and to advertise the VPN's public IP address pool:

```
[edit]
protocols {
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.171;
            family inet {
                any;
            }
            family inet-vpn {
                any;
            }
```

```
                export [ fix-nh redist-static];
                neighbor 10.255.14.177;
                neighbor 10.255.14.179;
            }
        }
```

Configure ISIS on router PE1 to allow access to internal routes:

```
    [edit protocols]
        isis {
            level 1 disable;
            interface so-0/0/0.0;
            interface lo0.0;
        }
```

Configure LDP on router PE1 to tunnel VPN routes:

```
    [edit protocols]
        ldp {
            interface so-0/0/0.0;
        }
    }
```

Configure a Routing Instance on Router PE1

Configure a routing instance on router PE1:

```
[edit]
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            bgp {
                group to-CE1 {
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Configure Policy Options on Router PE1

You need to configure policy options on router PE1. The fix-nh policy statement sets next-hop-self for all non-VPN routes:

```
[edit]
policy-options {
    policy-statement fix-nh {
        then {
            next-hop self;
        }
    }
```

The redist-static policy statement advertises the VPN's public IP address pool:

```
[edit policy-options]
  policy-statement redist-static {
    term a {
      from {
        protocol static;
        route-filter 10.12.1.0/24 exact;
      }
      then accept;
    }
    term b {
      then reject;
    }
  }
```

Configure import and export policies for vpna:

```
[edit policy-options]
  policy-statement vpna-import {
    term a {
      from {
        protocol bgp;
        community vpna-comm;
      }
      then accept;
    }
    term b {
      then reject;
    }
  }
  policy-statement vpna-export {
    term a {
      from protocol bgp;
      then {
        community add vpna-comm;
        accept;
      }
    }
    term b {
      then reject;
    }
  }
  community vpna-comm members target:63000:100;
}
```

Traffic Routed by Different Interfaces Configuration Summarized by Router

Router PE1

Interfaces

```
interfaces {
    t3-0/2/0 {
        dce;
        encapsulation frame-relay;
        unit 0 {
            description "to CE1 VPN interface";
            dlci 10;
            family inet {
                address 192.168.197.13/30;
            }
        }
        unit 1 {
            description "to CE1 public interface";
            dlci 20;
            family inet {
                address 192.168.198.201/30;
            }
        }
    }
}
```

Routing Options

```
routing-options {
    static {
        route 10.12.1.0/24 next-hop 192.168.198.202;
    }
}
```

BGP Protocol

```
protocols {
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.171;
            family inet {
                any;
            }
            family inet-vpn {
                any;
            }
            export [ fix-nh redist-static];
            neighbor 10.255.14.177;
            neighbor 10.255.14.179;
        }
    }
```

ISIS Protocol

```
    isis {
        level 1 disable;
        interface so-0/0/0.0;
        interface lo0.0;
    }
```

LDP Protocol

```
    ldp {
        interface so-0/0/0.0;
    }
}
```

Routing Instance

```
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            bgp {
                group to-CE1 {
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Policy Options / Policy Statements

```
policy-options {
    policy-statement fix-nh {
        then {
            next-hop self;
        }
    }
    policy-statement redist-static {
        term a {
            from {
                protocol static;
                route-filter 10.12.1.0/24 exact;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
```

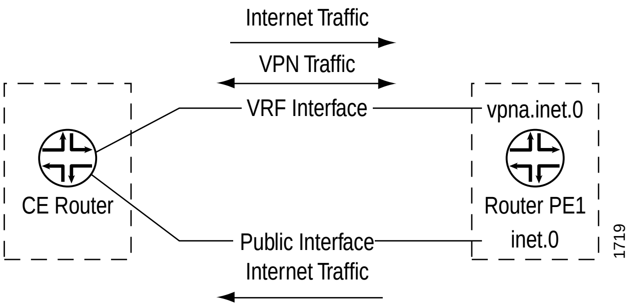
Import and Export Policies

```
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-export {
        term a {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vpna-comm members target:63000:100;
}
```

Route VPN and Outgoing Internet Traffic through the Same Interface and Route Return Internet Traffic through a Different Interface

In this example, the CE sends VPN and Internet traffic through the same interface but it receives return Internet traffic through a different interface. The PE router has a default route in the VRF table pointing to the main routing table inet.0. It routes the VPN public IP address pool (return Internet traffic) through a different interface in inet.0 (see Figure 31). The CE router still performs NAT functions.

Figure 31: VPN and Outgoing Internet Traffic Routed through the Same Interface and Return Internet Traffic Routed through a Different Interface



Configuration for Router PE1

This example has the same configuration as Router PE1 in “Route VPN and Internet Traffic through Different Interfaces” on page 201. It uses the topology shown in Figure 30, “Example of Internet Traffic Routed through Separate Interfaces” on page 202. The default route to the VPN routing table is configured differently. At the [edit routing-options] hierarchy level, you configure a default static route that is installed in vpna.inet.0 and points to inet.0 for resolution:

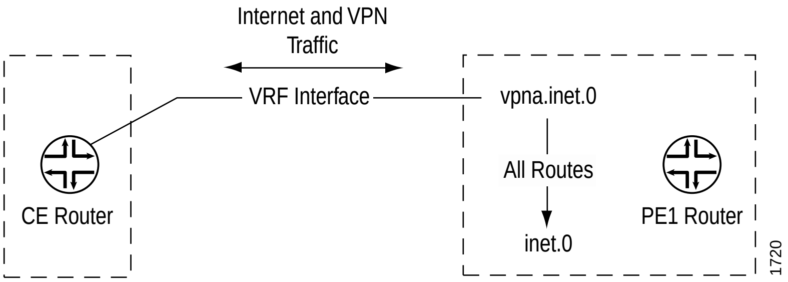
```
[edit routing-options]
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-table inet.0;
            }
        }
        protocols {
            bgp {
                group to-CE1 {
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

You also need to change the configuration of router CE1 (from a configuration for router CE1 that works in conjunction with the configuration for router PE1 described in “Route VPN and Internet Traffic through Different Interfaces” on page 201) to account for the differences in the configuration of the PE routers.

Route VPN and Internet Traffic through the Same Interface Bidirectionally (VPN Has Public Addresses)

This section shows how to configure a single logical interface to handle VPN and Internet traffic traveling both to and from the Internet and the CE router. This interface can handle both VPN and Internet traffic as long as there are no private addresses in the VPN. The VPN routes received from the CE router are added to the main routing table inet.0 using routing table groups. This allows the PE router to attract the return traffic from the Internet (see Figure 32).

Figure 32: Interface Configured to Carry Both Internet and VPN Traffic



In this example, the CE router does not need to perform NAT because all the VPN routes are public. The CE router has a single interface to the PE router, to which it advertises VPN routes. The PE router has a default route in the VRF table pointing to the main routing table inet.0. The PE router also imports VPN routes received from the CE router into inet.0 using routing table groups.

The following configuration for router PE1 uses the same topology as in “Route VPN and Internet Traffic through Different Interfaces” on page 201. This configuration uses a single logical interface (instead of two) between router PE1 and router CE1.

Configure Routing Options on Router PE1

Configure a routing table group definition for installing VPN routes in routing table groups vpna.inet.0 and inet.0:

```
[edit]
routing-options {
    rib-groups {
        vpna-to-inet0 {
            import-rib [ vpna.inet.0 inet.0 ];
        }
    }
```

Configure Routing Protocols on Router PE1

Configure MPLS, BGP, ISIS, and LDP protocols on router PE1. This configuration does not include the policy redist-static statement at the [edit protocols bgp group pe-pe] hierarchy level. The VPN routes are sent directly to IBGP.

Configure BGP on router PE1 to allow non-VPN and VPN peering, and to advertise the VPN's public IP address pool:

```
[edit]
protocols {
    mpls {
        interface t3-0/2/0.0;
    }
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.171;
            family inet {
                any;
            }
            family inet-vpn {
            any;
            }
            export fix-nh;
            neighbor 10.255.14.177;
            neighbor 10.255.14.173;
        }
    }
    isis {
        level 1 disable;
        interface so-0/0/0.0;
        interface lo0.0;
    }
    ldp {
        interface so-0/0/0.0;
    }
}
```

Configure the Routing Instance on Router PE1

This section describes how to configure the routing instance on router PE1. The static route defined in the routing-options statement directs Internet traffic from the CE router to the inet.0 routing table. The routing table group defined by the rib-group vpna-to-inet0 statement adds the VPN routes to inet.0.

Configure the routing instance on router PE1 as follows:

```
[edit]
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-table inet.0;
            }
        }
        protocols {
            bgp {
                group to-CE1 {
                    family inet {
                        unicast {
                            rib-group vpna-to-inet0;
                        }
                    }
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Note that you must configure router CE1 to forward all traffic to router PE1 using a default route. Alternatively, the default route can be advertised from router PE1 to router CE1 with EBGP.

Traffic Routed through the Same Interface Bidirectionally Configuration Summarized by Router

Router PE1

This example uses the same configuration as in “Route VPN and Internet Traffic through Different Interfaces” on page 201. This configuration uses a single logical interface (instead of two) between router PE1 and router CE1.

Routing Options

```
routing-options {
    rib-groups {
        vpna-to-inet0 {
            import-rib [ vpna.inet.0 inet.0 ];
        }
    }
}
```

Routing Protocols

```
protocols {
    mpls {
        interface t3-0/2/0.0;
    }
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.171;
            family inet {
                any;
            }
            family inet-vpn {
            any;
            }
            export fix-nh;
            neighbor 10.255.14.177;
            neighbor 10.255.14.173;
        }
    }
    isis {
        level 1 disable;
        interface so-0/0/0.0;
        interface lo0.0;
    }
    ldp {
        interface so-0/0/0.0;
    }
}
```

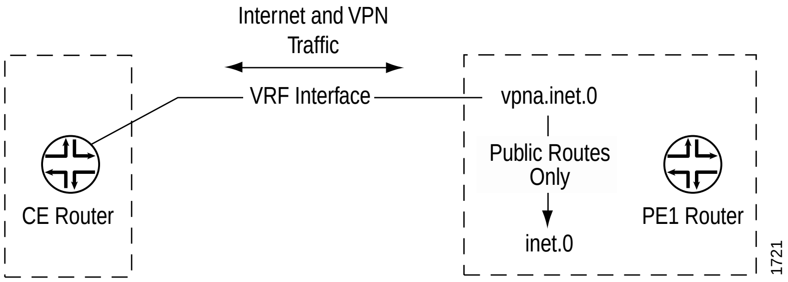
Routing Instance

```
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-table inet.0;
            }
        }
        protocols {
            bgp {
                group to-CE1 {
                    family inet {
                        unicast {
                            rib-group vpna-to-inet0;
                        }
                    }
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Route VPN and Internet Traffic through the Same Interface Bidirectionally (VPN Has Private Addresses)

The example in this section shows how to route VPN and Internet traffic through the same interface in both directions (from the CE router to the Internet and from the Internet to the CE router). The VPN in this example has private addresses. If you can configure EBGP on the CE router, you can configure a PE router using the configuration outlined in “Route VPN and Internet Traffic through the Same Interface Bidirectionally (VPN Has Public Addresses)” on page 209, even if the VPN has private addresses. In the example described in this section, the CE router uses separate communities to advertise its VPN routes and public routes. The PE router selectively imports only the public routes into the inet.0 routing table. This configuration ensures that return traffic from the Internet uses the same interface between the PE and CE routers as that used by VPN traffic going out to public Internet addresses (see Figure 33).

Figure 33: VPN and Internet Traffic Routed through the Same Interface



In this example, the CE router has one interface and a BGP session with the PE router, and it tags VPN routes and Internet routes with different communities. The PE router has one interface, selectively imports routes for the VPN’s public IP address pool into inet.0, and has a default route in the VRF routing table pointing to inet.0.

Configure Routing Options for Router PE1

On router PE1, you need to configure a routing table group to install VPN routes in the vpna.inet.0 and inet.0 routing tables:

```
[edit]
routing-options {
    rib-groups {
        vpna-to-inet0 {
            import-rib [ vpna.inet.0 inet.0 ];
        }
    }
}
```

Configure a Routing Instance for Router PE1

On router PE1, you need to configure a routing instance. As part of the configuration for the routing instance, you need to configure a static route that is installed in vpna.inet.0 and is pointed at inet.0 for resolution.

```
[edit]
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-table inet.0;
            }
        }
```

At the [edit routing-instances protocols bgp] hierarchy level, configure a policy (import-public-addr-to-inet0) to import public routes into inet.0 and a routing table group (vpna-to-inet0) to allow BGP to install routes into multiple routing tables (vpna.inet.0 and inet.0):

```
[edit routing-instances]
        protocols {
            bgp {
                group to-CE1 {
                    import import-public-addr-to-inet0;
                    family inet {
                        unicast {
                            rib-group vpna-to-inet0;
                        }
                    }
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Configure Policy Options for Router PE1

Configure the policy options for router PE1 to accept all routes initially (term a) and then to install routes with a public-comm community into routing table inet.0 (term b):

```
[edit]
policy-options {
    policy-statement import-public-addr-to-inet0 {
        term a {
            from {
                protocol bgp;
                rib vpna.inet.0;
                community [ public-comm private-comm ];
            }
            then accept;
        }
        term b {
            from {
                protocol bgp;
                community public-comm;
            }
            to rib inet.0;
            then accept;
        }
        term c {
            then reject;
        }
    }
    community private-comm members target:1:333;
    community public-comm members target:1:111;
    community vpna-comm members target:63000:100;
}
```

Traffic Routed by the Same Interface Bidirectionally (VPN Has Private Addresses) Configuration Summarized by Router

Router PE1

Routing Options

```
routing-options {
    rib-groups {
        vpna-to-inet0 {
            import-rib [ vpna.inet.0 inet.0 ];
        }
    }
}
```

Routing Instances

```
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-table inet.0;
            }
        }
```

Routing Instances Protocols BGP

```
        protocols {
            bgp {
                group to-CE1 {
                    import import-public-addr-to-inet0;
                    family inet {
                        unicast {
                            rib-group vpna-to-inet0;
                        }
                    }
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

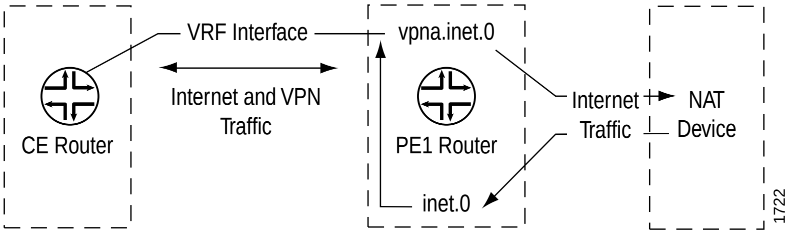
Policy Options

```
policy-options {
    policy-statement import-public-addr-to-inet0 {
        term a {
            from {
                protocol bgp;
                rib vpna.inet.0;
                community [ public-comm private-comm ];
            }
            then accept;
        }
        term b {
            from {
                protocol bgp;
                community public-comm;
            }
            to rib inet.0;
            then accept;
        }
        term c {
            then reject;
        }
    }
    community private-comm members target:1:333;
    community public-comm members target:1:111;
    community vpna-comm members target:63000:100;
}
```

Route Internet Traffic through a Separate NAT Device

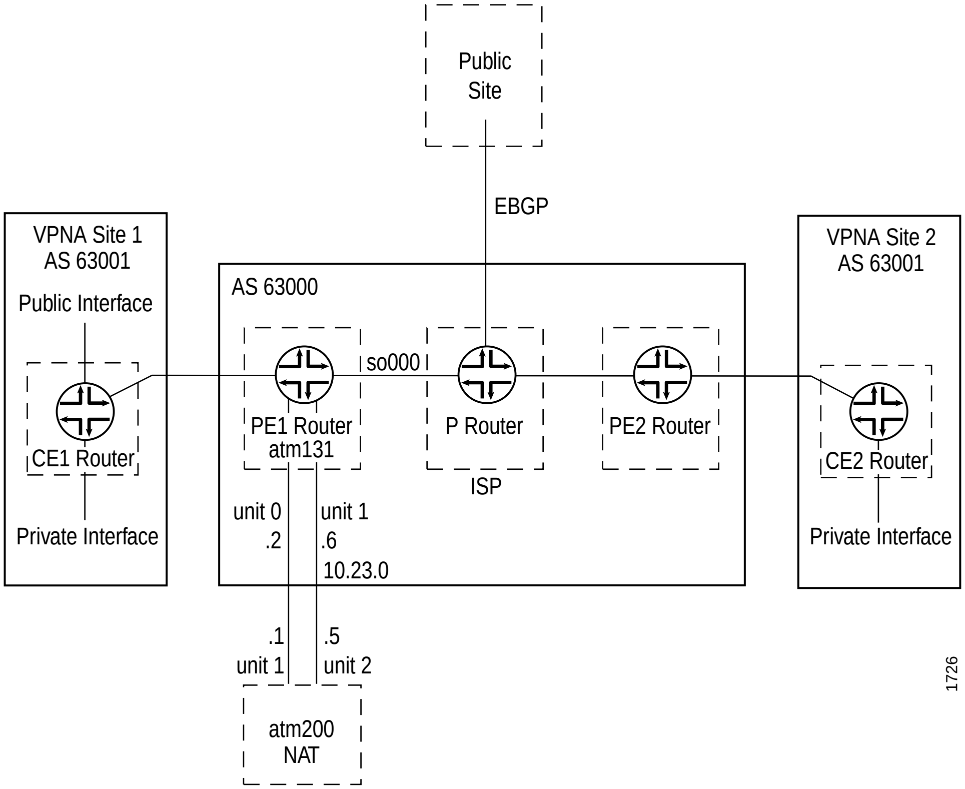
In this example, the CE router does not perform NAT. It sends both VPN and Internet traffic over the same interface to the PE router. The PE router is connected to a NAT device using two interfaces. One interface is configured in the PE router's VRF table and points to a VPN interface on the NAT device, which can route Internet traffic for the VPN. The other interface is in a default instance, for example, part of public routing table inet.0. There can be a single physical connection between the PE router and the NAT device and multiple logical connections—one for each VRF table and another interface—as part of the global routing table (see Figure 34).

Figure 34: Overview of Internet Traffic Routed through a Separate NAT Device



This example's topology expands upon that illustrated in Figure 30 on page 202. The CE router sends both VPN and Internet traffic to router PE1. VPN traffic is routed based on the VPN routes received by router PE1. Traffic for everything else is sent to the NAT device using router PE1's private interface to the NAT device, which then translates the private addresses and sends the traffic back to router PE1 using that router's public interface (see Figure 35).

Figure 35: Internet Traffic Routed through a Separate NAT Device Example Topology



Configure Interfaces on Router PE1

Configure an interface for VPN traffic to and from router CE1, an interface for VPN traffic to and from the NAT device, and an interface for Internet traffic to and from the NAT device:

```
[edit]
interfaces {
    t3-0/2/0 {
        dce;
        encapsulation frame-relay;
        unit 0 {
            description "to CE1 VPN interface";
            dlci 10;
            family inet {
                address 192.168.197.13/30;
            }
        }
    }
    at-1/3/1 {
        atm-options {
            vpi 1 maximum-vcs 255;
        }
        unit 0 {
            description "to NAT VPN interface";
            vci 1.100;
            family inet {
                address 10.23.0.2/32 {
                    destination 10.23.0.1;
                }
            }
        }
        unit 1 {
            description "to NAT public interface";
            vci 1.101;
            family inet {
                address 10.23.0.6/32 {
                    destination 10.23.0.5;
                }
            }
        }
    }
}
```

Configure Routing Options for Router PE1

You need to configure a static route on router PE1 to direct Internet traffic to the CE router through the NAT device. Router PE1 distributes this route to the Internet:

```
[edit]
routing-options {
    static {
        route 10.12.1.0/24 next-hop 10.23.0.5;
    }
}
```

Configure Routing Protocols on Router PE1

Configure MPLS, BGP, ISIS, and LDP on router PE1. For the MPLS configuration, include the NAT device's VPN interface in the VRF table. As a part of the BGP configuration, include a policy to advertise the public IP address pool:

```
[edit]
protocols {
    mpls {
        interface t3-0/2/0.0;
        interface at-1/3/1.0;
    }
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.171;
            family inet {
                any;
            }
            family inet-vpn {
                any;
            }
            export [ fix-nh redist-static ];
            neighbor 10.255.14.177;
            neighbor 10.255.14.173;
        }
    }
    isis {
        level 1 disable;
        interface so-0/0/0.0;
        interface lo0.0;
    }
    ldp {
        interface so-0/0/0.0;
    }
}
```

Configure a Routing Instance for Router PE1

Configure a routing instance on router PE1. As part of the routing instance configuration, under routing-options, configure a static default route in vpna.inet.0 pointing to the NAT device's VPN interface (this directs all non-VPN traffic to the NAT device):

```
[edit]
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        interface at-1/3/1.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-hop 10.23.0.1;
            }
        }
        protocols {
            bgp {
                group to-CE1 {
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
policy-options {
    policy-statement fix-nh {
        then {
            next-hop self;
        }
    }
    policy-statement redist-static {
        term a {
            from {
                protocol static;
                route-filter 10.12.1.0/24 exact;
            }
            then accept;
        }
        term b {
            from protocol bgp;
            then accept;
        }
        term c {
            then accept;
        }
    }
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-export {
        term a {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vpna-comm members target:63000:100;
}
```

Traffic Routed by Separate NAT Device Configuration Summarized by Router

Router PE1

Interfaces

```
interfaces {
    t3-0/2/0 {
        dce;
        encapsulation frame-relay;
        unit 0 {
            description "to CE1 VPN interface";
            dlci 10;
            family inet {
                address 192.168.197.13/30;
            }
        }
    }
    at-1/3/1 {
        atm-options {
            vpi 1 maximum-vcs 255;
        }
        unit 0 {
            description "to NAT VPN interface";
            vci 1.100;
            family inet {
                address 10.23.0.2/32 {
                    destination 10.23.0.1;
                }
            }
        }
        unit 1 {
            description "to NAT public interface";
            vci 1.101;
            family inet {
                address 10.23.0.6/32 {
                    destination 10.23.0.5;
                }
            }
        }
    }
}
```

Routing Options

```
routing-options {
    static {
        route 10.12.1.0/24 next-hop 10.23.0.5;
    }
}
```

Routing Protocols

```
protocols {
    mpls {
        interface t3-0/2/0.0;
        interface at-1/3/1.0;
    }
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.171;
            family inet {
                any;
            }
            family inet-vpn {
                any;
            }
            export [ fix-nh redist-static ];
            neighbor 10.255.14.177;
            neighbor 10.255.14.173;
        }
    }
    isis {
        level 1 disable;
        interface so-0/0/0.0;
        interface lo0.0;
    }
    ldp {
        interface so-0/0/0.0;
    }
}
```

Routing Instance

```
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        interface at-1/3/1.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-hop 10.23.0.1;
            }
        }
        protocols {
            bgp {
                group to-CE1 {
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Policy Options

```
policy-options {
    policy-statement fix-nh {
        then {
            next-hop self;
        }
    }
    policy-statement redist-static {
        term a {
            from {
                protocol static;
                route-filter 10.12.1.0/24 exact;
            }
            then accept;
        }
        term b {
            from protocol bgp;
            then accept;
        }
        term c {
            then accept;
        }
    }
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-export {
        term a {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vpna-comm members target:63000:100;
}
```

Centralized Internet Access

This section describes several ways to configure a CE router to act as a central site for Internet access. Internet traffic from other sites (CE routers) is routed to the hub CE router (which also performs NAT) using its VPN interface. The hub CE router then forwards the traffic to a PE router connected to the Internet through another interface identified in the inet.0 table. The hub CE router can advertise a default route to the spoke CE routers. The disadvantage of this type of configuration is that all traffic has to go through the central CE router before going to the Internet, causing network, delays if this router receives too much traffic. However, in a corporate network, traffic might have to be routed to a central site because most corporate networks separate the VPN from the Internet by means of a single firewall.

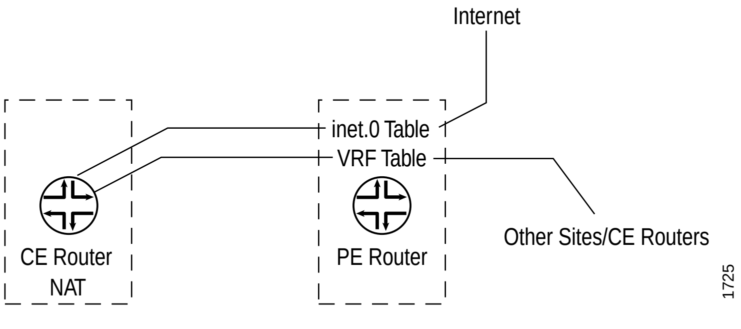
This section includes the following examples:

- Internet Traffic Routed by a Hub CE Router Configuration Summarized by Router on page 228
- Route Internet Traffic through Multiple CE Routers on page 229

Route Internet Traffic through a Hub CE Router

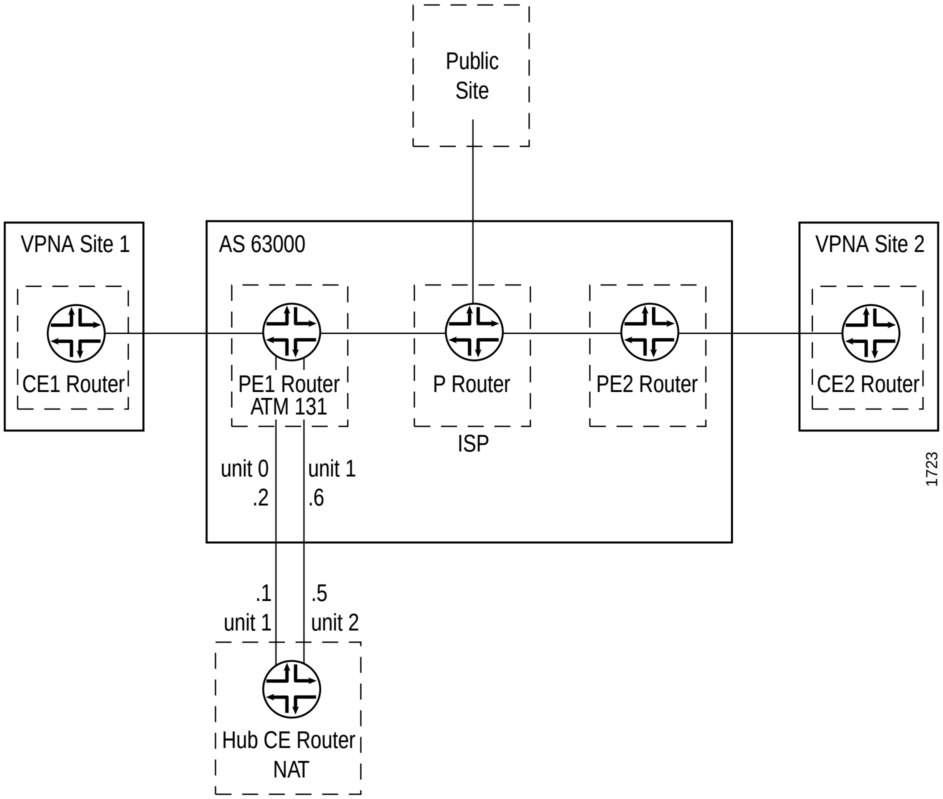
In this example, Internet traffic is routed through a hub CE router. The hub CE router has two interfaces to the hub PE router: a VPN interface and a public interface. It performs NAT on traffic forwarded from the hub PE router through the VPN interface and forwards that traffic from its public interface back to the hub PE router. The hub PE router has a static default route in its VRF table pointing to the hub CE router's VPN interface. It announces this default route to the rest of the VPN, attracting all non-VPN traffic to the hub CE route. The hub PE router also installs and distributes the VPN's public IP address space (see Figure 36).

Figure 36: Internet Access through a Hub CE Router Performing NAT



The configuration for this example is almost identical to that described in "Route Internet Traffic through a Separate NAT Device" on page 217. The difference is that router PE1 is configured to announce a static default route to the other CE routers (see Figure 37).

Figure 37: Internet Access Provided through a Hub CE Router



Configure a Routing Instance on Router PE1

Configure a routing instance for router PE1. As part of this configuration, under routing-options, configure a default static route (route 0.0.0.0/0) to be installed in vpna.inet.0 and point the route to the hub CE router's VPN interface (10.23.0.1). Also, configure BGP under the routing instance to export the default route to the local CE router:

```
[edit]
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        interface at-1/3/1.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-hop 10.23.0.1;
            }
        }
        protocols {
            bgp {
                group to-CE1 {
                    export export-default;
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Configure Policy Options on Router PE1

Configure policy options on router PE1. As part of this configuration, router PE1 should export the static default route to all the remote PE routers in vpna (configured in the policy-statement vpna-export statement under term b):

```
[edit]
policy-options {
    policy-statement vpna-export {
        term a {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term b {
            from {
                protocol static;
                route-filter 0.0.0.0/0 exact;
            }
            then {
                community add vpna-comm;
                accept;
            }
        }
        term c {
            then reject;
        }
    }
    policy-statement export-default {
        term a {
            from {
                protocol static;
                route-filter 0.0.0.0/0 exact;
            }
            then accept;
        }
        term b {
            from protocol bgp;
            then accept;
        }
        term c {
            then reject;
        }
    }
}
```

Internet Traffic Routed by a Hub CE Router Configuration Summarized by Router

Router PE1

The configuration for router PE1 is almost identical to that for the example in "Route Internet Traffic through a Separate NAT Device" on page 217. The difference is that router PE1 is configured to announce a static default route to the other CE routers.

Routing Instance

```
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        interface at-1/3/1.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-hop 10.23.0.1;
            }
        }
        protocols {
            bgp {
                group to-CE1 {
                    export export-default;
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Policy Options

```
policy-options {
    policy-statement vpna-export {
        term a {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term b {
            from {
                protocol static;
                route-filter 0.0.0.0/0 exact;
            }
            then {
                community add vpna-comm;
                accept;
            }
        }
        term c {
            then reject;
        }
    }
    policy-statement export-default {
        term a {
            from {
                protocol static;
                route-filter 0.0.0.0/0 exact;
            }
            then accept;
        }
        term b {
            from protocol bgp;
            then accept;
        }
        term c {
            then reject;
        }
    }
}
```

Route Internet Traffic through Multiple CE Routers

The example in this section is an extension of that described in “Route Internet Traffic through a Hub CE Router” on page 225. This example provides different exit points for different sites by using multiple hub CE routers performing similar functions. Each hub CE router tags the default route with a different route target and allows the spoke CE routers to select the hub site that should be used for Internet access (see Figure 38).

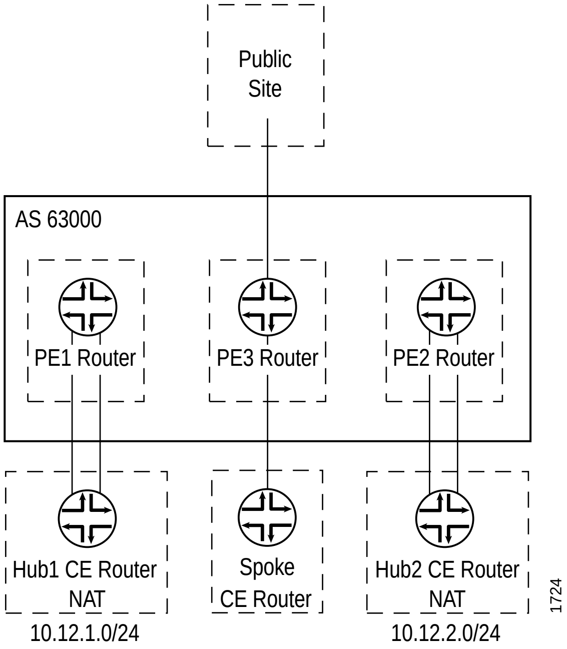
This example uses two hub CE routers that handle NAT and Internet traffic:

- Hub1 CE router tags 0/0 with community public-comm1 (target: 1:111)

- Hub2 CE router tags 0/0 with community public-comm2 (target: 1:112)

Note that the spoke CE router in this example is configured to have a bias toward Hub2 for Internet access.

Figure 38: Two Hub CE Routers Handling Internet Traffic and NAT



Configure a Routing Instance on Router PE1

Configure a routing instance on router PE1:

```
[edit]
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        interface at-1/3/1.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-hop 10.23.0.1;
            }
        }
        protocols {
            bgp {
                group to-CE1 {
                    export export-default;
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Configure Policy Options on Router PE1

The policy options for router PE1 are the same as in “Route Internet Traffic through a Hub CE Router” on page 225, but the configuration in this example includes an additional community, public-comm1, in the export statement:

```
[edit]
policy-options {
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-export {
        term a {
            from {
                protocol static;
                route-filter 0.0.0.0/0 exact;
            }
            then {
                community add public-comm1;
                community add vpna-comm;
                accept;
            }
        }
        term b {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term c {
            then reject;
        }
    }
    community public-comm1 members target:1:111;
    community public-comm2 members target:1:112;
    community vpna-comm members target:63000:100;
}
```

Note that the configuration of router PE2 is the identical to that of router PE1 except that router PE2 exports the default route through community public-comm2.

Configure a Routing Instance on Router PE3

Configure routing instance vpna on router PE3:

```
[edit]
routing-instances {
    vpna {
        instance-type vrf;
        interface t1-0/2/0.0;
        route-distinguisher 10.255.14.173:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            rip {
                group to-vpn12 {
                    export export-CE;
                    neighbor t1-0/2/0.0;
                }
            }
        }
    }
}
```

Configure Policy Options on Router PE3

The vrf-import policy for router PE3 is configured to select the Internet exit point based on the additional communities specified in “Configure Policy Options on Router PE1” on page 231:

```
[edit]
policy-options {
    policy-statement vpna-export {
        term a {
            from protocol rip;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community public-comm1;
                route-filter 0.0.0.0/0 exact;
            }
            then reject;
        }
        term b {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
```

```
                term c {
                    then reject;
                }
            }
            policy-statement export-CE {
                from protocol bgp;
                then accept;
            }
            community vpna-comm members target:69:100;
            community public-comm1 members target:1:111;
            community public-comm2 members target:1:112;
        }
```

Route Internet Traffic through Multiple CE Routers Configuration Summarized by Router

Router PE1

This configuration is an extension of the example in “Route Internet Traffic through a Hub CE Router” on page 225. It provides different exit points for various sites by using multiple hub CE routers that perform similar functions.

Routing Instance

```
routing-instances {
    vpna {
        instance-type vrf;
        interface t3-0/2/0.0;
        interface at-1/3/1.0;
        route-distinguisher 10.255.14.171:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        routing-options {
            static {
                route 0.0.0.0/0 next-hop 10.23.0.1;
            }
        }
        protocols {
            bgp {
                group to-CE1 {
                    export export-default;
                    peer-as 63001;
                    neighbor 192.168.197.14;
                }
            }
        }
    }
}
```

Policy Options

```
policy-options {
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-export {
        term a {
            from {
                protocol static;
                route-filter 0.0.0.0/0 exact;
            }
            then {
                community add public-comm1;
                community add vpna-comm;
                accept;
            }
        }
        term b {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term c {
            then reject;
        }
    }
    community public-comm1 members target:1:111;
    community public-comm2 members target:1:112;
    community vpna-comm members target:63000:100;
}
```

Router PE2

The configuration of router PE2 is the identical to that of router PE1, except that router PE2 exports the default route through community public-comm2 (see "Policy Options" on page 233).

Router PE3

Routing Instances

```
routing-instances {
    vpna {
        instance-type vrf;
        interface t1-0/2/0.0;
        route-distinguisher 10.255.14.173:100;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            rip {
                group to-vpn12 {
                    export export-CE;
                    neighbor t1-0/2/0.0;
                }
            }
        }
    }
}
```

Policy Options

```
policy-options {
    policy-statement vpna-export {
        term a {
            from protocol rip;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community public-comm1;
                route-filter 0.0.0.0/0 exact;
            }
            then reject;
        }
        term b {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term c {
            then reject;
        }
    }
    policy-statement export-CE {
        from protocol bgp;
        then accept;
    }
    community vpna-comm members target:69:100;
    community public-comm1 members target:1:111;
    community public-comm2 members target:1:112;
}
```

Chapter 11
Summary of Layer 3 VPN Configuration Statements

The following sections explain the major routing-instances configuration statements that apply specifically to Layer 3 virtual private networks (VPNs). The statements are organized alphabetically. Routing instances and the statements at the [edit routing-instances *routing-instance-name* routing-options] and [edit routing-instances *routing-instance-name* protocols] hierarchy levels are explained in the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

description

Syntax description *text*;

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description Allows you to provide a textual description for the routing instance. Enclose any descriptive text that includes spaces in quotation marks (" "). Any descriptive text you include is displayed in the output of the show route instance detail command and has no effect on the operation of the routing instance.

Usage Guidelines See “Configure the Description” on page 78.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

instance-type

Syntax instance-type vrf;

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description Defines the type of routing instance.

Options vrf—Virtual Routing and Forwarding instance. Required to create a VPN. Creates a Virtual Routing and Forwarding (VRF) table (*instance-name*.inet.0), which contains the routes originating from and destined for a particular VPN. You must configure the interface, route-distinguisher, vrf-import, and vrf-export statements for this type of routing instance.

Usage Guidelines See “Configure the Instance Type” on page 78.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

interface

Syntax interface *interface-name*;

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description Interface over which the VPN traffic travels between the provider edge (PE) router and customer edge (CE) router. You configure the interface on the PE router. If the instance type is vrf, the interface statement is required.

Usage Guidelines See "Configure Interfaces for VPN Routing" on page 78.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

route-distinguisher

Syntax route-distinguisher (*as-number*:*number* | *ip-address*:*number*);

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description Identifier attached to routes that distinguishes to which VPN it belongs. Each routing instance must have a unique route distinguisher associated with it. If the instance type is vrf, the route-distinguisher statement is required.

The route distinguisher is a 6-byte value that you can specify in one of the following formats:

- *as-number*:*number*, where *as-number* is your assigned AS number (a 2-byte value) and *number* is any 4-byte value. The AS number can be in the range of 1 through 65535.
- *ip-address*:*number*, where *ip-address* is an IP address in your assigned prefix range (a 4-byte value) and *number* is any 2-byte value. The IP address can be any globally unique unicast address.

Usage Guidelines See "Configure the Route Distinguisher" on page 79.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

vrf-export

Syntax vrf-export [*policy-names*];

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description How routes are exported from the local PE router's VRF table (*routing-instance-name*.inet.0) to the remote PE router. If the instance type is vrf, the vrf-export statement is required.

Options You can configure multiple export policies on the PE.

Usage Guidelines See "Configure Export Policy for the PE Router's VRF Table" on page 82.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

vrf-import

Syntax vrf-import [*policy-names*];

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description How routes are imported into the local PE router’s VRF table (*routing-instance-name*.inet.0) from the remote PE router. If the instance type is vrf, the vrf-import statement is required.

Options You can configure multiple import policies on the PE.

Usage Guidelines See “Configure Import Policy for the PE Router’s VRF Table” on page 81.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

vrf-table-label

Syntax vrf-table-label;

Hierarchy Level [edit routing-instances *routing-instance-name*]

Description Makes it possible to map the inner label of a packet to a specific VRF and thus allows the examination of the encapsulated IP header.

Usage Guidelines See “Filter Traffic Based on the IP Header” on page 84.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

Part 4

Interprovider and Carrier-of-Carriers VPNs

Chapter 12
Interprovider and Carrier-of-Carriers VPNs Overview

This chapter describes in detail the operation of interprovider and carrier-of-carriers virtual private networks (VPNs) as described in RFC 2547bis. As VPNs are deployed on the Internet, the customer of a VPN service provider might be another service provider rather than an end customer. The customer service provider depends on the VPN service provider to deliver a VPN transport service between the customer service provider's points of presence (POPs) or regional networks.

If the customer service provider's sites have different autonomous system (AS) numbers, then the VPN transit service provider supports interprovider VPN service. If the customer service provider's sites have the same AS number, then the VPN transit service provider delivers a carrier-of-carriers VPN service.

This chapter includes the following sections:

- Interprovider and Carrier-of-Carriers VPN Standards on page 243
- Traditional VPNs, Interprovider VPNs, and Carrier-of-Carriers VPNs on page 244
- Interprovider VPNs on page 245
- Carrier-of-Carriers VPNs on page 247

Interprovider and Carrier-of-Carriers VPN Standards

Interprovider and carrier-of-carriers VPNs are defined by the following documents:

- RFC 3107, *Carrying Label Information in BGP-4*.
- *BGP/MPLS VPNs*, Internet draft draft-ietf-ppvpn-rfc2547bis-00.txt.
- *RFC 2547bis: BGP/MPLS VPN Fundamentals*—a white paper located on the Juniper Web site at http://www.juniper.net/.

To access Internet RFCs and drafts, go to the IETF Web site at http://www.ietf.org/.

Traditional VPNs, Interprovider VPNs, and Carrier-of-Carriers VPNs

The sections that follow provide an overview of traditional VPNs, interprovider and carrier-of-carriers VPNs, and the differences in how external and internal routes are handled in each of these environments.

In traditional IP routing architectures, there is a clear distinction between internal routes and external routes. From the perspective of an ISP, internal routes include all the provider's internal links (including BGP next-hops) and loopback interfaces. These internal routes are exchanged with other routers in the ISP's network by means of an interior gateway protocol (IGP) such as Open Shortest Path First (OSPF) or Intermediate System to Intermediate System (IS-IS). All routes learned at Internet peering points or from customer sites are classified as external routes and are distributed using an exterior gateway protocol (EGP) such as the border gateway protocol (BGP). In traditional IP routing architectures, the number of internal routes is typically much smaller than the number of external routes.

Standard VPNs

The traditional distinction between internal routes and external routes also applies to VPN routing architectures. As shown in Figure 1 on page 4, the provider (P) routers maintain only the service provider's internal routes (to provider edge [PE] routers and other P routers); they do not maintain VPN routes. PE routers are the only devices in the provider network that are required to maintain external routes.

The BGP next-hop connects the external routes to the internal routes in traditional VPNs:

- The BGP next-hop is advertised with each external route in BGP advertisements.
- The route to the BGP next-hop is an internal route that is advertised by the IGP.
- Multiprotocol Label Switching (MPLS) provides packet-forwarding from the ingress PE router to the BGP next-hop egress PE router.

Interprovider and Carrier-of-Carriers VPNs

All interprovider and carrier-of-carriers VPNs share the following characteristics:

- Each interprovider or carrier-of-carriers VPN customer must distinguish between internal and external customer routes.
- Internal customer routes must be maintained by the VPN service provider in its PE routers.
- External customer routes are carried only by the customer's routers, not by the VPN service provider's routers.

The key difference between interprovider and carrier-of-carriers VPNs is whether the customer sites belong to the same AS or to separate ASs:

- Interprovider VPNs—The customer sites belong to different ASs. You need to configure EBGP to exchange the customer's external routes.
- Carrier-of-Carriers VPNs—The customer sites belong to the same AS. You need to configure IBGP to exchange the customer's external routes.

In general, each service provider in a VPN hierarchy is required to maintain its own internal routes in its provider routers, and the internal routes of its customers in its PE routers. By recursively applying this rule, it is possible to create a hierarchy of VPNs.

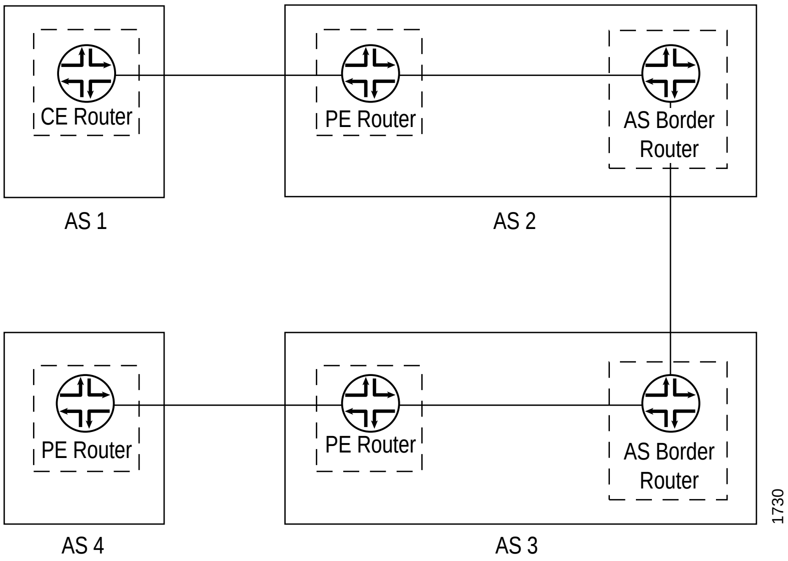
The following are definitions of the types of PE routers specific to interprovider and carrier-of-carriers VPNs:

- The AS border router is located at the AS border and handles traffic leaving and entering the AS.
- The end-PE router is the PE router in the customer VPN; it is connected to the customer edge (CE) router at the end customer's site.

Interprovider VPNs

Interprovider VPNs provide connectivity between separate ASs. This functionality might be used by a VPN customer who has connections to several different ISPs, or different connections to the same ISP in different geographic regions, each of which has a different AS. Figure 39 illustrates the type of network topology used by an interprovider VPN.

Figure 39: Interprovider VPN Network Topology



The following sections describe the ways you can configure an interprovider VPN:

- Interprovider VPNs—Linking VRF Tables Between Autonomous Systems on page 246
- Interprovider VPNs—Configure MP-IBGP Between AS Border Routers on page 246
- Interprovider VPNs—Configure Multihop MP-EBGP on page 246

Interprovider VPNs—Linking VRF Tables Between Autonomous Systems

You can connect two separate ASs by simply linking the virtual routing and forwarding (VRF) table in the AS border router of one AS to the VRF table in the AS border router in the other AS. Each AS border router must contain a VRF instance for every VPN configured in both service provider networks. You then configure an IP session between the two AS border routers. In effect, the AS border routers treat each other as CE routers.

Because of the complexity of the configuration, particularly with regard to scaling, this method is not recommended. The details of this configuration are not provided in this manual.

Interprovider VPNs—Configure MP-IBGP Between AS Border Routers

In this approach, the PE routers within an AS use multiprotocol-IBGP (MP-IBGP) to distribute labeled VPN-IPv4 routes to an AS border router or a route reflector of which the AS border router is a client. The AS border router uses MP-EBGP to distribute the labeled VPN-IPv4 routes to its peer AS border router in the neighboring AS. The peer AS border router then uses MP-IBGP to distribute labeled VPN-IPv4 routes to PE routers, or to a route reflector of which the PE routers are a client.

This approach enhances the scalability of an EBGP VRF-to-VRF configuration because it eliminates the need to configure all of the VPNs on every AS border router. However, it also introduces some complexity:

- All the VRF routes must be stored in the AS border router.
- An LSP must be established from ingress PE routers to egress PE routers.
- Secure connections must exist among the ASs along the path from the ingress PE router to the egress PE router.
- The ASs must be configured to know which AS border routers receive routes with specific route target attributes.

Interprovider VPNs—Configure Multihop MP-EBGP

In this type of interprovider VPN configuration, provider routers do not need to know all the routes in all the VPNs. Only the PE routers must have all the VPN routes. The provider routers simply forward traffic to the PE routers—they are not aware of the packets' destination. The connections between the AS border routers in separate ASs forward traffic between the ASs, much as a label-switched path (LSP) works.

The following are the basic steps you take to configure an interprovider VPN in this manner:

1. Configure multihop EBGP redistribution of labeled VPN-IPv4 routes between the source and destination ASs.
2. Configure EBGP to redistribute labeled IPv4 routes from its AS to neighboring ASs.
3. Configure MPLS on the end-PE routers of the VPNs.

Carrier-of-Carriers VPNs

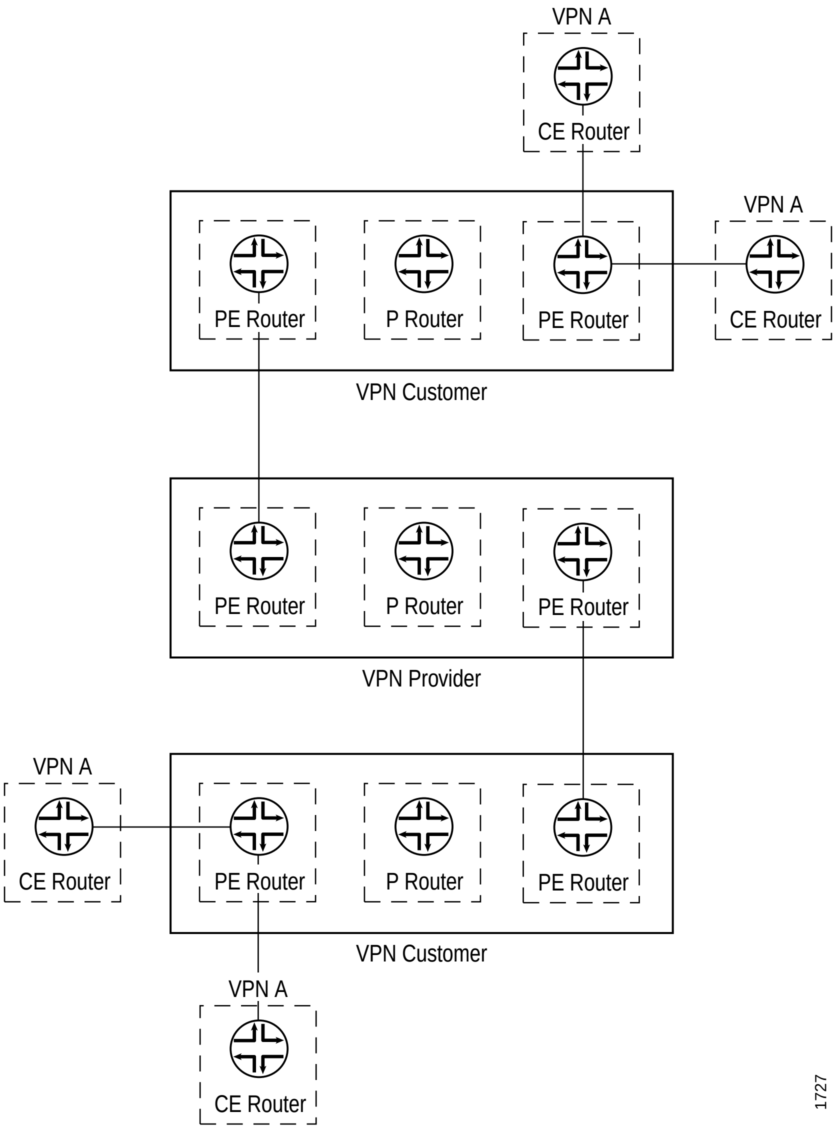
The customer of a VPN service provider might be a service provider for the end customer. The following are the two main types of carrier-of-carriers VPNs (as described in RFC 2547bis):

- Internet Service Provider as the Customer—The VPN customer is an ISP that uses the VPN service provider's network to connect its geographically disparate regional networks. The customer does not have to configure MPLS within its regional networks.

- VPN Service Provider as the Customer—The VPN customer is itself a VPN service provider offering VPN service to its customers. The carrier-of-carriers VPN service customer relies on the backbone VPN service provider for intersite connectivity. The customer VPN service provider is required to run MPLS within its regional networks.

Figure 40 illustrates the network architecture used for a carrier-of-carriers VPN service.

Figure 40: Carrier-of-Carriers VPN Architecture



Internet Service Provider as the Customer

In this type of carrier-of-carriers VPN configuration, ISP A configures its network to provide Internet service to ISP B. ISP B provides the connection to the customer wanting Internet service, but the actual Internet service is provided by ISP A.

This type of carrier-of-carriers VPN configuration has the following characteristics:

- The carrier-of-carriers VPN service customer (ISP B) does not need to configure MPLS on its network.
- The carrier-of-carriers VPN service provider (ISP A) must configure MPLS on its network.
- MPLS must also be configured on the CE routers and PE routers connected together in the carrier-of-carriers VPN service customer's and carrier-of-carriers VPN service provider's networks.

VPN Service Provider as the Customer

A VPN service provider can have customers that are themselves VPN service providers. In this type of configuration, also called a hierarchical or recursive VPN, the customer VPN service provider's VPN-IPv4 routes are considered external routes, and the backbone VPN service provider does not import them into its VRF table. The backbone VPN service provider only imports the customer VPN service provider's internal routes into its VRF.

This type of configuration is similar to the configuration described in the "Internet Service Provider as the Customer" section. The similarities and differences are show in Table 2.

Table 2: Comparison of Interprovider and Carrier-of-Carriers VPNs

Feature	ISP Customer	VPN Service Provider Customer
Customer edge device	AS border router	PE router
IBGP sessions	Carry IPv4 routes	Carry external VPN-IPv4 routes with associated labels
Forwarding within the customer network	MPLS is optional	MPLS is required

Chapter 13
Interprovider and Carrier-of-Carriers Configuration Guidelines

To configure interprovider or carrier-of-carriers virtual private network (VPN) functionality, you typically need to include the labeled-unicast statement in the configuration for Border Gateway Protocol (BGP) on the autonomous system (AS) border routers of an interprovider VPN or the PE and CE routers of a carrier-of-carrier VPN. You must also configure the provider (P) routers in the service providers and service customer's networks.

To configure interprovider or carrier-of-carriers VPN functionality, you include statements at the [edit protocols bgp] hierarchy level:

```
[edit]
protocols {
    bgp {
        group group-name {
            type internal;
            local-address address;
            family inet {
                labeled-unicast;
            }
            neighbor address;
        }
```

This chapter is divided into the following sections:

- Interprovider VPNs on page 251
- Carrier-of-Carriers VPNs on page 256

Interprovider VPNs

You can configure interprovider VPN service in either of the following ways:

- Interprovider VPNs Using MP-EBGP on page 252
- Interprovider VPNs Using Multihop MP-EBGP on page 254

Interprovider VPNs Using MP-EBGP

To configure interprovider VPN service using MP-EBGP, you need to configure the AS border routers of each AS. See Figure 39, "Interprovider VPN Network Topology," on page 245 for an illustration of how the routers interconnect in an interprovider VPN service.

Configure the AS Border Routers

The configuration of the AS border routers in each AS is nearly identical. You need to configure the following on each AS border router:

- Configure RSVP on page 252
- Configure MPLS on page 252
- Configure BGP on page 253
- Configure OSPF on page 253

Configure RSVP

Configure an interface for VPN traffic from the other AS to the PE router handling VPN traffic in the current AS at the [edit protocols rsvp] hierarchy level:

```
[edit]
protocols {
    rsvp {
        interface interface-name;
    }
```

Configure MPLS

Configure a label-switched path (LSP) to the PE router at the [edit protocols mpls] hierarchy level. Also configure the interfaces handling VPN traffic from the other AS and to the PE router in the current AS:

```
[edit]
protocols {
    mpls {
        label-switched-path path-name {
            to address;
        }
        interface interface-name;
        interface interface-name;
    }
```

Configure BGP

Configure an MP-EBGP session on the AS border router. This session exchanges VPN-IPv4 routes with the AS border router in the other AS.

Configure the MP-EBGP session at the [edit protocols bgp] hierarchy level. Configure a group to handle IBGP and a group to handle EBGP:

```
[edit]
protocols {
    bgp {
        keep all;
        group group-name;
            type internal;
            local-address address;
            family inet-vpn {
                unicast;
            }
            neighbor address;
        }
        group group-name {
            type external;
            family inet-vpn {
                unicast;
            }
            neighbor address {
                peer-as as number;
            }
        }
    }
}
```

Configure OSPF

Configure OSPF on the AS border router at the [edit protocols ospf] hierarchy level as follows:

```
[edit]
protocols {
    ospf {
        traffic engineering;
        area address {
            interface interface-name;
            interface interface-name {
                passive;
            }
        }
    }
}
```

Interprovider VPNs Using Multihop MP-EBGP

This section describes how to configure a network to provide interprovider VPN service using multihop MP-EBGP. With this type of configuration, you need to set up the AS border routers and the PE routers connected to the end customer's CE routers. See Figure 39, "Interprovider VPN Network Topology," on page 245 for an illustration of how the routers interconnect in an interprovider VPN service.

Configure the AS Border Routers

The configuration of the AS border routers in each AS is nearly identical. You need to configure the following on each AS border router:

- Configure BGP on page 254
- Configure Policy Options on page 255

Configure BGP

Configure BGP on the AS border routers at the [edit protocols bgp] hierarchy level. Configure a group for IBGP and a group for EBGP to the PE router:

```
[edit]
protocols {
    bgp {
        group group-name {
            type internal;
            local-address address;
            family inet {
                labeled-unicast {
                    resolve-vpn;
                }
            }
            neighbor address;
        }
        group group-name {
            type external;
            family inet {
                labeled-unicast;
            }
            export internal;
            neighbor address {
                peer-as as-number;
            }
        }
    }
}
```

Configure Policy Options

Configure the policy options on the AS border routers as follows at the [edit policy-options] hierarchy level:

```
[edit]
policy-options {
    policy-statement policy-name {
        term term-name {
            from protocol [ospf direct];
            then accept;
        }
        term term-name {
            then reject;
        }
    }
}
```

Configure the PE Router

You need to configure a multihop MP-EBGP session on the PE router connected to the end customer's CE router.

Include the labeled-unicast statement at the [edit protocols bgp group family inet] hierarchy level to pass labeled IPv4 routes:

```
[edit]
protocols {
    bgp {
        group group-name {
            type internal;
            local-address address;
            family inet {
                labeled-unicast {
                    resolve-vpn;
            }
            neighbor address;
        }
    }
}
```

Configure a group at the [edit protocols bgp] hierarchy level to handle an EBGP multihop session with the remote PE router (to pass VPN-IPv4 routes):

```
[edit]
protocols {
    bgp {
        group group-name {
            multihop {
                ttl 10;
            }
            family inet-vpn {
                unicast;
            }
        neighbor address {
            peer-as as-number;
        }
    }
}
```

Carrier-of-Carriers VPNs

You can configure carrier-of-carriers VPNs service in one of the following ways:

- Carrier-of-Carriers VPN—Customer Provides Internet Service on page 256
- Carrier-of-Carriers VPN—Customer Provides VPN Service on page 260

Carrier-of-Carriers VPN—Customer Provides Internet Service

In this type of carrier-of-carriers VPN service configuration, the customer provides basic Internet service. The carrier-of-carriers VPN service provider must configure MPLS in its network, though this is optional for the carrier service customer. Figure 40, "Carrier-of-Carriers VPN Architecture," on page 248 shows how the routers in this type of service interconnect.

This section describes the following:

- Configure the Carrier-of-Carriers VPN Service Customer's CE Router on page 256
- Configure the Carrier-of-Carriers VPN Service Provider's PE Routers on page 258

Configure the Carrier-of-Carriers VPN Service Customer's CE Router

The carrier-of-carriers VPN service customer's router acts as a CE router with respect to service provider's PE router. This section describes how to configure the carrier-of-carriers VPN service customer's CE router.

Configure MPLS

Configure MPLS at the [edit protocols mpls] hierarchy level as follows on the customer's CE router:

```
[edit]
protocols {
    mpls {
        traffic-engineering bgp-igp;
        interface interface-name;
    }
}
```

Configure BGP

Configure a group at the `[edit protocols bgp]` hierarchy level to collate the customer's internal routes:

```
[edit]
protocols {
    bgp {
        group group-name {
            type internal;
            local-address address;
            neighbor address;
        }
    }
}
```

The customer's CE router must be able to send labels to the VPN service provider's router. Enable this by including the `labeled-unicast` statement at the `[edit protocols bgp group neighbor family inet]` hierarchy level.

```
[edit]
protocols {
    bgp {
        group group-name {
            export internal;
            peer-as as-number;
            neighbor address {
                family inet {
                    labeled-unicast;
                }
            }
        }
    }
}
```

Configure OSPF

Configure OSPF at the `[edit protocols ospf]` hierarchy level on the customer's CE router as follows:

```
[edit]
protocols {
    ospf {
        area area-id {
            interface interface-name {
                passive;
            }
            interface interface-name;
        }
    }
}
```

Configure Policy Options

Configure policy options at the [edit policy-options] hierarchy level on the customer's CE router as follows:

```
[edit]
policy-options {
    policy-statement statement-name {
        term term-name {
            from protocol [ospf direct ldp];
            then accept;
        }
        term term-name {
            then reject;
        }
    }
}
```

Configure the Carrier-of-Carriers VPN Service Provider's PE Routers

The service provider's PE routers connect to the customer's CE routers and forward the customer's VPN traffic across the provider's network.

Configure MPLS

Configure MPLS at the [edit protocols mpls] hierarchy level on the provider's PE routers as follows:

```
[edit]
protocols {
    mpls {
        interface interface-name;
        interface interface-name;
    }
}
```

Configure BGP

Configure a BGP session at the [edit protocols bgp] hierarchy level with the provider PE router at the other end of the provider's network:

```
[edit]
protocols {
    bgp {
        group group-name {
            type internal;
            local-address address;
            family inet-vpn {
                any;
            }
            neighbor address;
        }
    }
}
```

Configure IS-IS

Configure IS-IS at the [edit protocols isis] hierarchy level on the provider’s PE routers:

```
[edit]
protocols {
    isis {
        interface interface-name;
        interface interface-name {
            passive;
        }
    }
}
```

Configure LDP

Configure LDP at the [edit protocols ldp] hierarchy level on the provider’s PE routers:

```
[edit]
protocols {
    ldp {
        interface interface-name;
    }
}
```

Configure a Routing Instance

At the [edit routing-instances] hierarchy level, configure layer 3 VPN service with the customer’s CE router. Note that you include the labeled-unicast statement within the routing instance so the PE router can send labels to the customer’s CE router:

```
[edit]
routing-instances {
    routing-instance-name {
        instance-type vrf;
        interface interface-name;
        route-distinguisher address;
        vrf-import policy-name;
        vrf-export policy-name;
        protocols {
            bgp {
                group group-name {
                    peer-as as-number;
                    neighbor address {
                        family inet {
                            labeled-unicast;
                        }
                    }
                }
            }
        }
    }
}
```

Configure Policy Options

Configure a policy statement at the [edit policy-options] hierarchy level to import routes from the customer’s CE router:

```
[edit]
policy-options {
    policy-statement policy-name {
        term term-name {
            from {
                protocol bgp;
                community community-name;
            }
            then accept;
        }
        term term-name {
            then reject;
        }
    }
}
```

Configure a policy statement to export routes to the customer’s CE router:

```
[edit]
policy-options {
    policy-statement policy-name {
        term term-name {
            from protocol bgp;
            then {
                community add community-name;
                accept;
            }
        }
        term term-name {
            then reject;
        }
    }
    community community-name members value;
}
```

Carrier-of-Carriers VPN—Customer Provides VPN Service

Figure 40, “Carrier-of-Carriers VPN Architecture,” on page 248 shows how the routers in this type of service interconnect.

Configure the following routers in the customer’s and provider’s networks to enable carrier-of-carriers VPN service:

- Configure the Carrier-of-Carriers Customer’s PE Router on page 261
- Configure the Carrier of Carriers Customer’s CE Router on page 263
- Configure the Provider’s PE Router on page 265

Configure the Carrier-of-Carriers Customer's PE Router

The carrier-of-carriers customer's PE router is connected to the end customer's CE router.

Configure MPLS

Configure MPLS at the [edit protocols mpls] hierarchy level on the carrier-of-carriers customer's PE router as follows:

```
[edit]
protocols {
    mpls {
        interface interface-name;
        interface interface-name;
    }
}
```

Configure BGP

Configure the labeled-unicast statement at the [edit protocols bgp] hierarchy level on the IBGP session to the carrier-of-carriers customer's CE router (see "Configure the Carrier of Carriers Customer's CE Router" on page 263) and configure the family-inet-vpn statement for the IBGP session to the carrier-of-carriers PE router on the other side of the network:

```
[edit]
protocols {
    bgp {
        group group-name {
            type internal;
            local-address address;
            neighbor address {
                family inet {
                    labeled-unicast;
                    resolve-vpn;
                }
            }
        }
        neighbor address {
            family inet-vpn {
                any;
            }
        }
    }
}
```

Configure OSPF

Configure OSPF at the [edit protocols ospf] hierarchy level on the carrier-of-carriers customer's PE router:

```
[edit]
protocols {
    ospf {
        area area-id {
            interface interface-name {
                passive;
            }
            interface interface-name;
        }
    }
```

Configure LDP

Configure label distribution protocol (LDP) at the [edit protocols ldp] hierarchy level on the carrier-of-carriers customer's PE router:

```
[edit]
protocols {
    ldp {
        interface interface-name;
    }
}
```

Configure VPN Service in the Routing Instance

Configure VPN service for the end customer's CE router at the [edit routing-instances *routing-instance-name*] hierarchy level on the carrier-of-carriers customer's PE router:

```
[edit]
routing-instances {
    routing-instance-name {
        instance-type vrf;
        interface interface-name;
        route-distinguisher address;
        vrf-import policy-name;
        vrf-export policy-name;
        protocols {
            bgp {
                group group-name {
                    peer-as as-number;
                    neighbor address;
                }
            }
        }
    }
}
```

Configure Policy Options

Configure policy options at the [edit policy-options] hierarchy level to import and export routes to and from the end customer's CE router:

```
[edit]
policy-options {
    policy-statement policy-name {
        term term-name {
            from {
                protocol bgp;
                community community-name;
            }
            then accept;
        }
        term term-name {
            then reject;
        }
    }
    policy-statement policy-name {
        term term-name {
            from protocol bgp;
            then {
                community add community-name;
                accept;
            }
        }
        term term-name {
            then reject;
        }
    }
    community community-name members value;
}
```

Configure the Carrier of Carriers Customer's CE Router

The carrier-of-carriers customer's CE router connects to the provider's PE router.

Configure MPLS

In the MPLS configuration for the carrier-of-carriers customer's CE router, include the interfaces to the provider's PE router and to a provider router in the customer's network:

```
[edit]
protocols {
    mpls {
        traffic-engineering bgp-igp;
        interface interface-name;
        interface interface-name;
    }
}
```

Configure BGP

In the BGP configuration for the carrier-of-carriers customer's CE router at the [edit protocols bgp] hierarchy level, configure a group that includes the labeled-unicast statement to extend VPN service to the PE router connected to the end customer's CE router:

```
[edit]
protocols {
    bgp {
        group group-name {
            type internal;
            local-address address;
            neighbor address {
                family inet {
                    labeled-unicast;
                }
            }
        }
    }
}
```

Configure a group to send labeled internal routes to the provider's PE router:

```
[edit]
protocols {
    bgp {
        group group-name {
            export internal;
            peer-as as-number;
            neighbor address {
                family inet {
                    labeled-unicast;
                }
            }
        }
    }
}
```

Configure OSPF and LDP

Configure OSPF and LDP at the [edit protocols] hierarchy level on the carrier-of-carriers customer's CE router:

```
[edit]
protocols {
    ospf {
        area area-id {
            interface interface-name {
                passive;
            }
            interface interface-name;
        }
    }
    ldp {
        interface interface-name;
    }
}
```

Configure Policy Options

Configure the policy options at the [edit policy-options] hierarchy level on the carrier-of-carriers customer's CE router as follows:

```
[edit]
policy-options {
    policy-statement policy-statement-name {
        term term-name {
            from protocol [ ospf direct ldp ];
            then accept;
        }
        term term-name {
            then reject;
        }
    }
}
```

Configure the Provider's PE Router

The carrier-of-carriers provider's PE routers connect to the carrier customer's CE routers.

Configure MPLS

Configure at least two interfaces at the [edit protocols mpls] hierarchy level—one to the customer's CE router and one to connect to the provider's PE router on the other side of the provider's network:

```
[edit]
protocols {
    mpls {
        interface interface-name;
        interface interface-name;
    }
}
```

Configure a PE-router-to-PE-router BGP Session

Configure a PE-router-to-PE-router BGP session at the [edit protocols bgp] hierarchy level on the provider's PE routers to allow VPN-IPv4 routes to pass between the PE routers:

```
[edit]
protocols {
    bgp {
        group group-name {
            type internal;
            local-address address;
            family inet-vpn {
                any;
            }
            neighbor address;
        }
    }
}
```

Configure IS-IS and LDP

Configure IS-IS and LDP at the [edit protocols] hierarchy level on the provider's PE routers as follows:

```
[edit]
protocols {
    isis {
        interface interface-name;
        interface interface-name {
            passive;
        }
    }
    ldp {
        interface interface-name;
    }
}
```

Configure Policy Options

Configure policy statements at the [edit policy-options] hierarchy level on the provider's PE router to export routes to and import routes from the carrier customer's network:

```
[edit]
policy-options {
    policy-statement statement-name {
        term term-name {
            from {
                protocol bgp;
                community community-name;
            }
            then accept;
        }
        term term-name {
            then reject;
        }
    }
    policy-statement statement-name {
        term term-name {
            from protocol bgp;
            then {
                community add community-name;
                accept;
            }
        }
        term term-name {
            then reject;
        }
    }
    community community-name members value;
}
```

Configure a Routing Instance to Send Labeled Routes to the CE Router

Configure the routing instance at the [edit routing-instances] hierarchy level on the provider's PE router to send labeled routes to the carrier customer's CE router:

```
[edit]
routing-instances {
    routing-instance-name {
        instance-type vrf;
        interface interface-name;
        route-distinguisher value;
        vrf-import policy-name;
        vrf-export policy-name;
        protocols {
            bgp {
                group group-name {
                    peer-as as-number;
                    neighbor address {
                        family inet {
                            labeled-unicast;
                        }
                    }
                }
            }
        }
    }
}
```

Chapter 14
Configuration Examples for Interprovider and Carrier-of-Carriers VPNs

This chapter contains examples that illustrate how to configure interprovider and carrier-of-carriers VPNs. It includes the following sections:

Example Terminology

The following terminology is used in these examples and is specific to Juniper Networks:

- bgp.l3vpn.0: The table on the provider edge (PE) router in which the VPN-IPv4 routes that are received from another PE router are stored. Incoming routes are checked against the vrf-import statements from all the VPNs configured on the PE router. If there is a match, the VPN-IPv4 route is added to the bgp.l3vpn.0 table. To view the bgp.l3vpn.0 table, issue the show route table bgp.l3vpn.0 command.
- *routing-instance-name*.inet.0: The routing table for a specific routing instance. For example, a routing instance called VPN-A has a routing table called VPN-A.inet.0. Routes are added to this table in the following ways:
  - They are sent from a customer edge (CE) router configured within the VPN-A routing instance.
  - They are advertised from a remote PE router that passes the vrf-import policy configured within VPN-A (to view the route, run the show route command). IPv4 (not VPN-IPv4) routes are stored in this table.
- vrf-import *policy-name*: An import policy configured on a particular routing instance on a PE router. This policy is required for the configuration of interprovider and carrier-of-carriers VPNs. It is applied to VPN-IPv4 routes learned from another PE outer or a route reflector.

- vrf-export *policy-name*: An export policy configured on a particular routing instance on a PE router. It is required for the configuration of interprovider and carrier-of-carriers VPNs. It is applied to VPN-IPv4 routes, (originally learned from locally connected CE routers as IPv4 routes), which are advertised to another PE router or route reflector.

- MP-EBGP: The multiprotocol BGP mechanism is used to export VPN-IPv4 routes across an AS boundary. To apply this mechanism, use the labeled-unicast statement at the [edit protocols bgp group *group-name* family inet] hierarchy level.

Interprovider VPN Examples

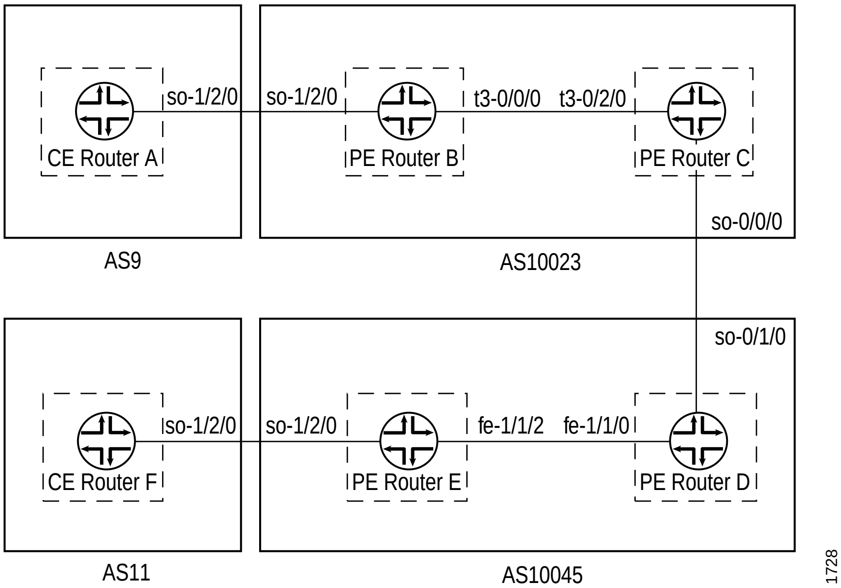
The following examples illustrate how to configure interprovider VPNs:

- Interprovider VPN Example—MP-EBGP Between ISP Peer Routers on page 271

- Interprovider VPN Example—Multihop MP-EBGP on page 277

Figure 41 illustrates the network topology used in both VPN examples.

Figure 41: Network Topology of Interprovider VPN Examples



Interprovider VPN Example—MP-EBGP Between ISP Peer Routers

In this example, all routes learned from the CE routers are sent over both service provider networks as VPN-IPv4 routes. The routes are initially learned by the PE routers (router B and router E) from the CE routers (router A and router F) and are announced by the PE routers to the AS border routers (router C and router D). The AS border routers are then configured with a multiprotocol EBGP session enabling them to pass the VPN-IPv4 routes with each other. When an AS border router—router C for example—learns VPN-IPv4 routes from an IBGP PE, the following occurs:

1. Router C sets itself as the nexthop for the route and creates a label for that route.

2. Router C advertises the VPN-IPv4 route to PE router D in AS 10045.

3. Router D sets the next-hop to itself, creates another label, and then forwards the label and the route to its IBGP PE router (router E).

This example has scaling limitations because of restrictions on the number of labels each PE router needs to allocate at the AS border.

Configuration for Router A

Configure a family inet EBGP session with router B and export the direct routes:

```
[edit]
protocols {
    bgp {
        group to-provider {
            export attached;
            peer-as 10023;
            neighbor 192.168.198.2;
        }
    }
}
policy-options {
    policy-statement attached {
        from protocol direct;
        then accept;
    }
}
```

Configuration for Router B

Router A is configured as a CE router (using the routing-instances statement) in the configuration for router B. Because they exchange VPN-IPv4 routes, router D and router C are configured as PE routers.

Configure router B as follows:

```
[edit]
protocols {
    rsvp {
        interface t3-0/0/0.0;
    }
    mpls {
        label-switched-path to-routerC {
            to 10.255.14.171;
            description "to-routerC for use with VPNs";
        }
        interface t3-0/0/0.0;
        interface so-1/2/0.0;
    }
    bgp {
        group to-ibgp {
            type internal;
            local-address 10.255.14.175;
            family inet-vpn {
                unicast;
            }
            neighbor 10.255.14.171;
        }
    }
    ospf {
        traffic-engineering;
        reference-bandwidth 4g;
        area 0.0.0.0 {
            interface t3-0/0/0.0;
            interface lo0.0 {
                passive;
            }
        }
    }
}
routing-instances {
    vpna {
        instance-type vrf;
        interface so-1/2/0.0;
        route-distinguisher 10.255.14.175:9;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            bgp {
                group to-ce {
                    peer-as 9;
                    neighbor 192.168.198.1;
                }
            }
        }
    }
}
```

```
policy-options {
    policy-statement vpna-import {
        term 1 {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term 2 {
            then reject;
        }
    }
    policy-statement vpna-export {
        term 1 {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term 2 {
            then reject;
        }
    }
    community vpna-comm members target:100:1001;
}
```

Configuration for Router C

In the BGP protocol configuration for router C, include the keep all statement. This forces BGP to store every route learned through BGP. Configure two BGP sessions (configure family inet-vpn on both sessions):

- IBGP session to router D (group to-ibgp in this example)
- EBGP session to router B (group to-ebgp-pe in this example)

Also note that interface t3-0/2/0 is added at the [edit protocols mpls] hierarchy level, which allows BGP to announce routes with labels over the EBGP session.

Configure router C as follows:

```
[edit]
protocols {
    rsvp {
        interface t3-0/2/0.0;
    }
    mpls {
        label-switched-path to-routerB {
            to 10.255.14.175;
            description "to-routerB for use with vpns";
        }
        interface t3-0/2/0.0;
        interface so-0/0/0.0;
    }
    bgp {
        keep all;
        group to-ibgp {
            type internal;
            local-address 10.255.14.171;
            family inet-vpn {
                unicast;
            }
            neighbor 10.255.14.175;
        }
        group to-ebgp-pe {
            type external;
            family inet-vpn {
                unicast;
            }
            neighbor 192.168.197.22 {
                peer-as 10045;
            }
        }
    }
    ospf {
        traffic-engineering;
        reference-bandwidth 4g;
        area 0.0.0.0 {
            interface t3-0/2/0.0;
            interface lo0.0 {
                passive;
            }
        }
    }
}
```

Configure for Router D

The configuration for router D is almost identical to that of router C:

```
[edit]
protocols {
    rsvp {
        interface fe-1/1/0.0;
    }
    mpls {
        label-switched-path to-E {
            to 10.255.14.177;
            description "to-routerE for vpna";
        }
        interface fe-1/1/0.0;
        interface so-0/1/0.0;
    }
    bgp {
        keep all;
        group to-ibgp-pe {
            type internal;
            family inet-vpn {
                unicast;
            }
            neighbor 10.255.14.177;
        }
        group to-ebgp-pe {
            type external;
            family inet-vpn {
                unicast;
            }
            peer-as 10023;
            neighbor 192.168.197.21;
        }
    }
    ospf {
        traffic-engineering;
        reference-bandwidth 4g;
        area 0.0.0.0 {
            interface fe-1/1/0.0;
            interface lo0.0 {
                passive;
            }
        }
    }
}
```

Configuration for Router E

The configuration for router E is very similar to the configuration for router B:

```
[edit]
protocols {
    rsvp {
        interface fe-1/1/2.0;
    }
    mpls {
        label-switched-path to-routerD {
            to 10.255.14.173;
            description "to-routerD for use with VPNa";
        }
        interface fe-1/1/2.0;
        interface so-1/2/0.0;
    }
    bgp {
        group to-ibgp-pe {
            type internal;
            local-address 10.255.14.177;
            family inet-vpn {
                unicast;
            }
            neighbor 10.255.14.173;
        }
    }
    ospf {
        traffic-engineering;
        reference-bandwidth 4g;
        area 0.0.0.0 {
            interface fe-1/1/2.0;
            interface lo0.0 {
                passive;
            }
        }
    }
}
routing-instances {
    vpna {
        instance-type vrf;
        interface so-1/2/0.0;
        route-distinguisher 10.255.14.177:11;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            bgp {
                group to-routerF-ce {
                    neighbor 192.168.198.14 {
                        peer-as 11;
                    }
                }
            }
        }
    }
}
policy-options {
    policy-statement vpna-import {
        term 1 {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term 2 {
            then reject;
        }
    }
    policy-statement vpna-export {
        term 1 {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term 2 {
            then reject;
        }
    }
    community vpna-comm members target:100:1001;
}
```

Configuration for Router F

Configure router F as a CE router; the configuration is similar to that for router A:

```
[edit]
protocols {
    bgp {
        group to-provider {
            type external;
            export attached;
            neighbor 192.168.198.13 {
                peer-as 10045;
            }
        }
    }
}
policy-options {
    policy-statement attached {
        from protocol direct;
        then accept;
    }
}
```

Interprovider VPN Example—Multihop MP-EBGP

In this example, labeled IPv4 (not VPN-IPv4) routes are exchanged by the AS border routers (router C and router D) to provide MPLS connectivity between the PE routers. Only routes internal to the service provider networks should be announced between router C and router D. Configure this by including the family inet labeled-unicast statement in the IBGP and EBGP configuration on the PE routers. When you set family inet labeled-unicast, the local router announces internal routes from inet.0 in the following manner:

- If a label exists for the route, the local router creates a label, performs a swap, and announces the route from inet.0 with the label.
- If a label does not exist for the route, the local router creates a label, performs a pop, and announces the route from inet.0 with the label.

Routes learned from the labeled-unicast session are placed into the inet.0 routing table.

In addition, you configure a multihop MP-EBGP session between the end PE routers (router B and router E). This additional MP-EBGP session allows the announcement of VPN-IPv4 routes, and allows you to maintain VPN connectivity while keeping VPN-IPv4 routes out of the core of the network.

> **Note** The configurations for the routers in the “Interprovider VPN Example—Multihop MP-EBGP” section are similar to those for the routers in the “Interprovider VPN Example—MP-EBGP Between ISP Peer Routers” section. In the sections that follow, only the differences in these configurations are shown. The configurations for router A and router F are the same so they are not repeated.

Configuration for Router B

In group to-ibgp, include the family inet labeled-unicast statement to pass labeled IPv4 routes and configure an EBGP multihop session to pass VPN-IPv4 routes:

```
[edit]
protocols {
    bgp {
        group to-ibgp {
            type internal;
            local-address 10.255.14.175;
            family inet {
                labeled-unicast;
            }
            neighbor 10.255.14.171;
        }
        group to-remote-pe {
            multihop {
                ttl 10;
            }
            family inet-vpn {
                unicast;
            }
        neighbor 10.255.14.177 {
            peer-as 10045;
        }
    }
}
```

Configuration for Router C

Configure router C as follows:

```
[edit]
protocols {
    bgp {
        group to-ibgp {
            type internal;
            local-address 10.255.14.171;
            family inet {
                labeled-unicast;
            }
            neighbor 10.255.14.175;
        }
        group to-ebgp-pe {
            type external;
            family inet {
                labeled-unicast;
            }
            export internal;
            neighbor 192.168.197.22 {
                peer-as 10045;
            }
        }
    }
}
```

```
policy-options {
    policy-statement internal {
        term 1 {
            from protocol [ ospf direct ];
            then accept;
        }
        term 2 {
            then reject;
        }
    }
}
```

Configuration for Router D

Configure router D as follows:

```
[edit]
protocols {
    bgp {
        group to-ibgp-pe {
            type internal;
            family inet {
                labeled-unicast;
            }
            neighbor 10.255.14.177;
        }
        group to-ebgp-pe {
            type external;
            family inet {
                labeled-unicast;
            }
            export internal;
            peer-as 10023;
            neighbor 192.168.197.21;
        }
    }
}
policy-options {
    policy-statement internal {
        term 1 {
            from protocol [ direct ospf ];
            then accept;
        }
        term 2 {
            then reject;
        }
    }
}
```

Configuration for Router E

Configure router E as follows:

```
[edit]
protocols {
    bgp {
        group to-ibgp-pe {
            type internal;
            local-address 10.255.14.177;
            family inet {
                labeled-unicast;
            }
            neighbor 10.255.14.173;
        }
        group to-remote-pe {
            multihop {
                ttl 10;
            }
            family inet-vpn {
                unicast;
            }
        neighbor 10.255.14.175 {
            peer-as 10023;
        }
    }
}
```

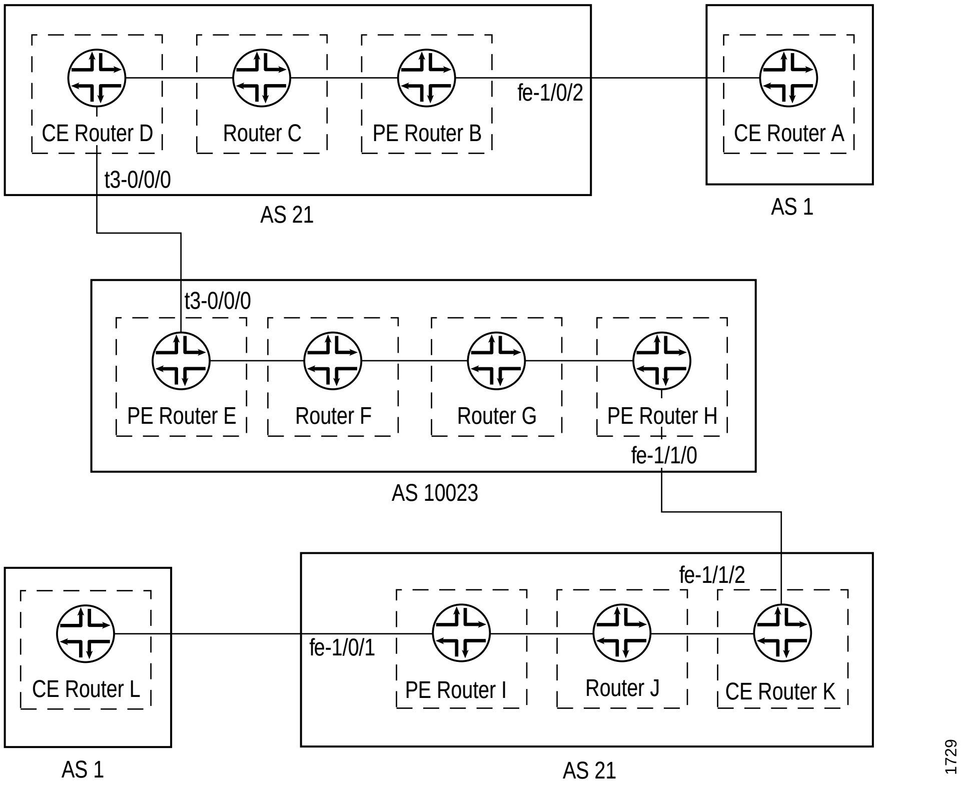
Carrier-of-Carriers VPN Examples

A carrier-of-carriers service allows an ISP to connect to a transparent outsourced backbone at multiple locations. There are two variations of this example:

- Carrier-of-Carriers VPN Example—Customer Provides Internet Service on page 282
- Carrier-of-Carriers VPN Example—Customer Provides VPN Service on page 291

Figure 42 shows the network topology in both carrier-of-carriers examples.

Figure 42: Carrier-of-Carriers VPN Example Network Topology



Carrier-of-Carriers VPN Example—Customer Provides Internet Service

In this example, the carrier customer is not required to configure MPLS and LDP on its network. However, the carrier provider must configure MPLS and LDP on its network.

Configuration for Router A

In this example, router A represents an end customer. You configure this router as a CE device.

```
[edit]
protocols {
    bgp {
        group to-routerB {
            export attached;
            peer-as 21;
            neighbor 192.168.197.169;
        }
    }
}
policy-options {
    policy-statement attached {
        from protocol direct;
        then accept;
    }
}
```

Configuration for Router B

Router B can act as the gateway router, responsible for aggregating end customers and connecting them to the network. Note that if a full-mesh IBGP session is configured, you can use route reflectors.

```
[edit]
protocols {
    bgp {
        group int {
            type internal;
            local-address 10.255.14.179;
            neighbor 10.255.14.175;
            neighbor 10.255.14.181;
            neighbor 10.255.14.176;
            neighbor 10.255.14.178;
            neighbor 10.255.14.177;
        }
        group to-vpn-blue {
            peer-as 1;
            neighbor 192.168.197.170;
        }
    }
```

```
        ospf {
            area 0.0.0.0 {
                interface lo0.0 {
                    passive;
                }
                interface fe-1/0/3.0;
                interface fe-1/0/2.0 {
                    passive;
                }
            }
        }
    }
```

Configuration for Router C

Configure router C:

```
[edit]
protocols {
    bgp {
        group int {
            type internal;
            local-address 10.255.14.176;
            neighbor 10.255.14.179;
            neighbor 10.255.14.175;
            neighbor 10.255.14.177;
            neighbor 10.255.14.178;
            neighbor 10.255.14.181;
        }
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-0/3/3.0;
            interface fe-0/3/0.0;
        }
    }
}
```

Configuration for Router D

Router D is the CE router with respect to AS 10023. In a carrier-of-carriers VPN, the CE router must be able to send labels to the carrier provider; this is done with the labeled-unicast statement in group to-isp-red.

```
[edit]
protocols {
    mpls {
        interface t3-0/0/0.0;
    }
    bgp {
        group int {
            type internal;
            local-address 10.255.14.175;
            neighbor 10.255.14.179;
            neighbor 10.255.14.176;
            neighbor 10.255.14.177;
            neighbor 10.255.14.178;
            neighbor 10.255.14.181;
        }
        group to-isp-red {
            export internal;
            peer-as 10023;
            neighbor 192.168.197.13 {
                family inet {
                    labeled-unicast;
                }
            }
        }
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-0/3/0.0;
            interface t3-0/0/0.0 {
                passive;
            }
        }
    }
}
policy options {
    policy-statement internal {
        term a {
            from protocol [ ospf direct ];
            then accept;
        }
        term b {
            then reject;
        }
    }
}
```

Configuration for Router E

This configuration sets up the inet-vpn IBGP session with router H and the PE router portion of the VPN with router D. Because router D is required to send labels in this example, configure the BGP session with the labeled-unicast statement within the virtual routing and forwarding (VRF) table.

```
[edit]
protocols {
    mpls {
        interface t3-0/2/0.0;
        interface at-0/1/0.0;
    }
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.171;
            family inet-vpn {
                any;
            }
            neighbor 10.255.14.173;
        }
    }
    isis {
        interface at-0/1/0.0;
        interface lo0.0 {
            passive;
        }
    }
    ldp {
        interface at-0/1/0.0;
    }
}
routing-instances {
    vpn-isp1 {
        instance-type vrf;
        interface t3-0/2/0.0;
        route-distinguisher 10.255.14.171:21;
        vrf-import vpn-isp1-import;
        vrf-export vpn-isp1-export;
        protocols {
            bgp {
                group to-isp1 {
                    peer-as 21;
                    neighbor 192.168.197.14 {
                        family inet {
                            labeled-unicast;
                        }
                    }
                }
            }
        }
    }
}
```

```
policy-options {
    policy-statement vpn-isp1-import {
        term a {
            from {
                protocol bgp;
                community vpn-isp1-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpn-isp1-export {
        term a {
            from protocol bgp;
            then {
                community add vpn-isp1-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vpn-isp1-comm members target:69:21;
}
```

Configuration for Router F

Configure router F to act as a label-swapping router:

```
[edit]
protocols {
    isis {
        interface so-0/2/0.0;
        interface at-0/3/0.0;
        interface lo0.0 {
            passive;
        }
    }
    ldp {
        interface so-0/2/0.0;
        interface at-0/3/0.0;
    }
}
```

Configuration for Router G

Configure router G to act as a label-swapping router:

```
[edit]
protocols {
    isis {
        interface so-0/0/0.0;
        interface so-1/0/0.0;
        interface lo0.0 {
            passive;
        }
    }
    ldp {
        interface so-0/0/0.0;
        interface so-1/0/0.0;
    }
}
```

Configuration for Router H

Router H acts as the PE router for AS 10023. The configuration that follows is similar to that for router F:

```
[edit]
protocols {
    mpls {
        interface fe-1/1/0.0;
        interface so-1/0/0.0;
    }
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.173;
            family inet-vpn {
                any;
            }
            neighbor 10.255.14.171;
        }
    }
    isis {
        interface so-1/0/0.0;
        interface lo0.0 {
            passive;
        }
    }
    ldp {
        interface so-1/0/0.0;
    }
}
```

```
routing-instances {
    vpn-isp1 {
        instance-type vrf;
        interface fe-1/1/0.0;
        route-distinguisher 10.255.14.173:21;
        vrf-import vpn-isp1-import;
        vrf-export vpn-isp1-export;
        protocols {
            bgp {
                group to-isp1 {
                    peer-as 21;
                    neighbor 192.168.197.94 {
                        family inet {
                            labeled-unicast;
                        }
                    }
                }
            }
        }
    }
}
policy-options {
    policy-statement vpn-isp1-import {
        term a {
            from {
                protocol bgp;
                community vpn-isp1-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpn-isp1-export {
        term a {
            from protocol bgp;
            then {
                community add vpn-isp1-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vpn-isp1-comm members target:69:21;
}
```

Configuration for Router I

Configure router I to connect to the basic Internet service customer (router L):

```
[edit]
protocols {
    mpls {
        interface fe-1/0/1.0;
        interface fe-1/1/3.0;
    }
    bgp {
        group int {
            type internal;
            local-address 10.255.14.181;
            neighbor 10.255.14.177;
            neighbor 10.255.14.179;
            neighbor 10.255.14.175;
            neighbor 10.255.14.176;
            neighbor 10.255.14.178;
        }
        group to-vpn-green {
            peer-as 1;
            neighbor 192.168.197.198;
        }
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-1/0/1.0 {
                passive;
            }
            interface fe-1/1/3.0;
        }
    }
}
```

Configuration for Router J

Configure router J as a label-swapping router:

```
[edit]
protocols {
    bgp {
        group int {
            type internal;
            local-address 10.255.14.178;
            neighbor 10.255.14.177;
            neighbor 10.255.14.181;
            neighbor 10.255.14.175;
            neighbor 10.255.14.176;
            neighbor 10.255.14.179;
        }
    }
}
```

```
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-1/0/2.0;
            interface fe-1/0/3.0;
        }
    }
}
```

Configuration for Router K

Router K acts as the CE router at the end of the connection to the carrier provider. As in the configuration for router D, you include the labeled-unicast statement for the EBGP session:

```
[edit]
protocols {
    mpls {
        interface fe-1/1/2.0;
        interface fe-1/0/2.0;
    }
    bgp {
        group int {
            type internal;
            local-address 10.255.14.177;
            neighbor 10.255.14.181;
            neighbor 10.255.14.178;
            neighbor 10.255.14.175;
            neighbor 10.255.14.176;
            neighbor 10.255.14.179;
        }
        group to-isp-red {
            export internal;
            peer-as 10023;
            neighbor 192.168.197.93 {
                family inet {
                    labeled-unicast;
                }
            }
        }
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-1/0/2.0;
            interface fe-1/1/2.0 {
                passive;
            }
        }
    }
}
```

```
policy-options {
    policy-statement internal {
        term a {
            from protocol [ ospf direct ];
            then accept;
        }
        term b {
            then reject;
        }
    }
}
```

Configuration for Router L

Configure router L to act as the end customer for the carrier-of-carriers VPN service:

```
[edit]
protocols {
    bgp {
        group to-routerl {
            export attached;
            peer-as 21;
            neighbor 192.168.197.197;
        }
    }
}
policy-options {
    policy-statement attached {
        from protocol direct;
        then accept;
    }
}
```

Carrier-of-Carriers VPN Example—Customer Provides VPN Service

In this example, the carrier customer *must* run some form of MPLS (resource reservation protocol [RSVP] or label distribution protocol [LDP]) on its network to provide VPN services to the end customer. In example below, router B and router I act as PE routers, and a functioning MPLS path is required between these routers if they exchange VPN-IPv4 routes.

Configuration for Router A

In this example, router A acts as the CE router for the end customer. Configure a default family inet BGP session on router A:

```
[edit]
protocols {
    bgp {
        group to-routerB {
            export attached;
            peer-as 21;
            neighbor 192.168.197.169;
        }
    }
}
policy-options {
    policy-statement attached {
        from protocol direct;
        then accept;
    }
}
```

Configuration for Router B

Router B is the PE router for the end customer CE router (router A), so you need to configure a routing instance (vpna). Configure the labeled-unicast statement on the IBGP session to router D, and configure family-inet-vpn for the IBGP session to the other side of the network (see Figure 42 on page 281) with router I:

```
[edit]
protocols {
    mpls {
        interface fe-1/0/2.0;
        interface fe-1/0/3.0;
    }
    bgp {
        group int {
            type internal;
            local-address 10.255.14.179;
            neighbor 10.255.14.175 {
                family inet {
                    labeled-unicast;
                    resolve-vpn;
                }
            }
        }
        neighbor 10.255.14.181 {
            family inet-vpn {
                any;
            }
        }
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-1/0/3.0;
        }
    }
    ldp {
        interface fe-1/0/3.0;
    }
}
routing-instances {
    vpna {
        instance-type vrf;
        interface fe-1/0/2.0;
        route-distinguisher 10.255.14.179:21;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            bgp {
                group vpna-06 {
                    peer-as 1;
                    neighbor 192.168.197.170;
                }
            }
        }
    }
}
policy-options {
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-export {
        term a {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vpna-comm members target:100:1001;
}
```

Configuration for Router C

Configure router C as a label-swapping router within the local AS:

```
[edit]
protocols {
    mpls {
        traffic-engineering bgp-igp;
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-0/3/3.0;
            interface fe-0/3/0.0;
        }
    }
    ldp {
        interface fe-0/3/0.0;
        interface fe-0/3/3.0;
    }
}
```

Configuration for Router D

Router D acts as the CE router for the VPN services provided by the AS 10023 network. In group int, you configure the labeled-unicast statement to router B (10.255.14.179). You also need to configure the BGP group to-isp-red to send labeled internal routes to the PE router (router E).

```
[edit]
protocols {
    mpls {
        traffic-engineering bgp-igp;
        interface fe-0/3/0.0;
        interface t3-0/0/0.0;
    }
    bgp {
        group int {
            type internal;
            local-address 10.255.14.175;
            neighbor 10.255.14.179 {
                family inet {
                    labeled-unicast;
                }
            }
        }
        group to-isp-red {
            export internal;
            peer-as 10023;
            neighbor 192.168.197.13 {
                family inet {
                    labeled-unicast;
                }
            }
        }
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-0/3/0.0;
        }
    }
    ldp {
        interface fe-0/3/0.0;
    }
}
policy-options {
    policy-statement internal {
        term a {
            from protocol [ ospf direct ];
            then accept;
        }
        term b {
            then reject;
        }
    }
}
```

Configuration for Router E

Router E and router H are PE routers. Configure a PE-router-to-PE-router BGP session to allow VPN-IPv4 routes to pass between these two PE routers. Configure the routing instance on router E to send labeled routes to the CE router (D).

Configure router E as follows:

```
[edit]
protocols {
    mpls {
        interface t3-0/2/0.0;
        interface at-0/1/0.0;
    }
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.171;
            family inet-vpn {
                any;
            }
            neighbor 10.255.14.173;
        }
    }
    isis {
        interface at-0/1/0.0;
        interface lo0.0 {
            passive;
        }
    }
    ldp {
        interface at-0/1/0.0;
    }
}
```

```
policy-options {
    policy-statement vpn-isp1-import {
        term a {
            from {
                protocol bgp;
                community vpn-isp1-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpn-isp1-export {
        term a {
            from protocol bgp;
            then {
                community add vpn-isp1-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vpn-isp1-comm members target:69:21;
}
routing-instances {
    vpn-isp1 {
        instance-type vrf;
        interface t3-0/2/0.0;
        route-distinguisher 10.255.14.171:21;
        vrf-import vpn-isp1-import;
        vrf-export vpn-isp1-export;
        protocols {
            bgp {
                group to-isp1 {
                    peer-as 21;
                    neighbor 192.168.197.14 {
                        family inet {
                            labeled-unicast;
                        }
                    }
                }
            }
        }
    }
}
```

Configuration for Router F

Configure router F to swap labels for routes running through its interfaces:

```
[edit]
protocols {
    isis {
        interface so-0/2/0.0;
        interface at-0/3/0.0;
        interface lo0.0 {
            passive;
        }
    }
    ldp {
        interface so-0/2/0.0;
        interface at-0/3/0.0;
    }
}
```

Configuration for Router G

Configure router G as follows:

```
[edit]
protocols {
    isis {
        interface so-0/0/0.0;
        interface so-1/0/0.0;
        interface lo0.0 {
            passive;
        }
    }
    ldp {
        interface so-0/0/0.0;
        interface so-1/0/0.0;
    }
}
```

Configuration for Router H

The configuration for router H is similar to the configuration for router E:

```
[edit]
protocols {
    mpls {
        interface fe-1/1/0.0;
        interface so-1/0/0.0;
    }
    bgp {
        group pe-pe {
            type internal;
            local-address 10.255.14.173;
            family inet-vpn {
                any;
            }
            neighbor 10.255.14.171;
        }
    }
    isis {
        interface so-1/0/0.0;
        interface lo0.0 {
            passive;
        }
    }
    ldp {
        interface so-1/0/0.0;
    }
}
routing-instances {
    vpn-isp1 {
        instance-type vrf;
        interface fe-1/1/0.0;
        route-distinguisher 10.255.14.173:21;
        vrf-import vpn-isp1-import;
        vrf-export vpn-isp1-export;
        protocols {
            bgp {
                group to-isp1 {
                    peer-as 21;
                    neighbor 192.168.197.94 {
                        family inet {
                            labeled-unicast;
                        }
                    }
                }
            }
        }
    }
}
policy-options {
    policy-statement vpn-isp1-import {
        term a {
            from {
                protocol bgp;
                community vpn-isp1-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpn-isp1-export {
        term a {
            from protocol bgp;
            then {
                community add vpn-isp1-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vpn-isp1-comm members target:69:21;
}
```

Configuration for Router I

Router I acts as the PE router for the end customer. The configuration that follows is similar to the configuration for router B:

```
[edit]
protocols {
    mpls {
        interface fe-1/0/1.0;
        interface fe-1/1/3.0;
    }
    bgp {
        group int {
            type internal;
            local-address 10.255.14.181;
            neighbor 10.255.14.177 {
                family inet {
                    labeled-unicast {
                        resolve-vpn;
                    }
                }
            }
            neighbor 10.255.14.179 {
                family inet-vpn {
                    any;
                }
            }
        }
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-1/1/3.0;
        }
    }
    ldp {
        interface fe-1/1/3.0;
    }
}
routing-instances {
    vpna {
        instance-type vrf;
        interface fe-1/0/1.0;
        route-distinguisher 10.255.14.181:21;
        vrf-import vpna-import;
        vrf-export vpna-export;
        protocols {
            bgp {
                group vpna-0 {
                    peer-as 1;
                    neighbor 192.168.197.198;
                }
            }
        }
    }
}
```

```
policy-options {
    policy-statement vpna-import {
        term a {
            from {
                protocol bgp;
                community vpna-comm;
            }
            then accept;
        }
        term b {
            then reject;
        }
    }
    policy-statement vpna-export {
        term a {
            from protocol bgp;
            then {
                community add vpna-comm;
                accept;
            }
        }
        term b {
            then reject;
        }
    }
    community vpna-comm members target:100:1001;
}
```

Configuration for Router J

Configure router J to swap labels for routes running through its interfaces:

```
[edit]
protocols {
    mpls {
        traffic-engineering bgp-igp;
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-1/0/2.0;
            interface fe-1/0/3.0;
        }
    }
    ldp {
        interface fe-1/0/2.0;
        interface fe-1/0/3.0;
    }
}
```

Configuration for Router K

The configuration for router K is similar to the configuration for router D:

```
[edit]
protocols {
    mpls {
        traffic-engineering bgp-igp;
        interface fe-1/1/2.0;
        interface fe-1/0/2.0;
    }
    bgp {
        group int {
            type internal;
            local-address 10.255.14.177;
            neighbor 10.255.14.181 {
                family inet {
                    labeled-unicast;
                }
            }
        }
        group to-isp-red {
            export internal;
            peer-as 10023;
            neighbor 192.168.197.93 {
                family inet {
                    labeled-unicast;
                }
            }
        }
    }
    ospf {
        area 0.0.0.0 {
            interface lo0.0 {
                passive;
            }
            interface fe-1/0/2.0;
        }
    }
    ldp {
        interface fe-1/0/2.0;
    }
}
policy-options {
    policy-statement internal {
        term a {
            from protocol [ ospf direct ];
            then accept;
        }
        term b {
            then reject;
        }
    }
}
```

Configuration for Router L

In this example, router L is the end customer's CE router. Configure router L as follows:

```
[edit]
protocols {
    bgp {
        group to-l {
            export attached;
            peer-as 21;
            neighbor 192.168.197.197;
        }
    }
}
policy-options {
    policy-statement attached {
        from protocol direct;
        then accept;
    }
}
```

Multiple Instances for LDP and Carrier of Carriers VPNs

By configuring multiple LDP routing instances, you can use LDP to advertise labels in a Carrier of Carriers VPN from a core provider PE router to a customer carrier CE router. This is especially useful when the carrier customer is a basic Internet Service Provider (ISP) and wants to restrict full Internet routes to its PE routers. By using LDP instead of BGP, the carrier customer shields its other internal routers from the Internet at large. Multiple instance LDP is also useful when a carrier customer wants to provide Layer 3 VPN or Layer 2 VPN services to its customers.

For an example of how to configure multiple LDP routing instances for carrier-of-carriers VPNs, see the *JUNOS Internet Software Feature Guide* on the product documentation page of the Juniper Networks Web site, located at http://www.juniper.net/.

Chapter 15
Summary of the Interprovider and Carrier-of-Carriers Configuration Statement

The following section explains the configuration statement that applies specifically to hierarchical and recursive Border Gateway Protocol (BGP) and Multiprotocol Label Switching (MPLS) virtual private networks (VPNs).

labeled-unicast

Syntax

```
labeled-unicast {
    resolve-vpn;
}
```

Hierarchy Level [edit protocols bgp group *group-name* family inet]

Description This statement advertises labeled routes from the inet.0 VPN and places labeled routes into the inet.0 VPN. When the labeled-unicast statement is used, the local router automatically performs next-hop to self on all routes advertised into External Border Gateway Protocol (EBGP) from Internal Border Gateway Protocol (IBGP) and IBGP to EBGP.

Options resolve-vpn—(Optional) Stores labeled routes in the inet.3 table to resolve routes for a PE router located in a different AS. Note that for a PE router to install a route in the VRF, the nexthop must resolve to a route stored within the inet.3 table.

Usage Guidelines See “Interprovider and Carrier-of-Carriers Configuration Guidelines” on page 251.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

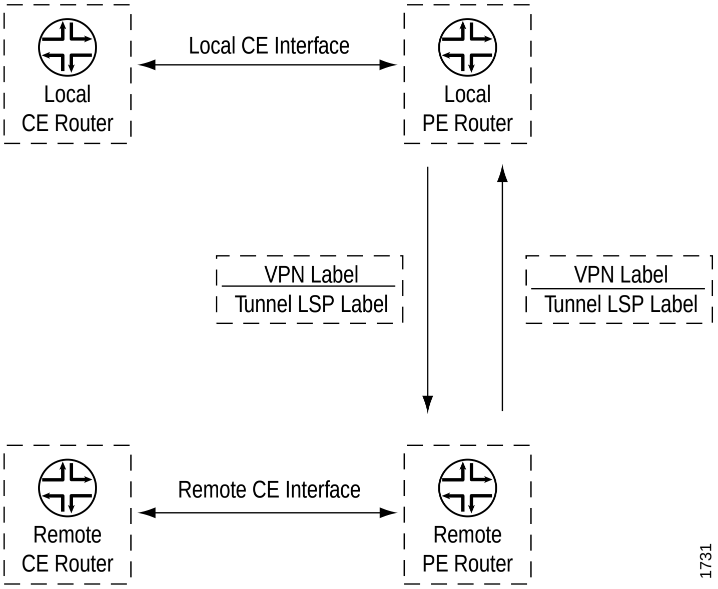
Part 5
Layer 2 Circuits

Chapter 16
Layer 2 Virtual Circuits Configuration Guidelines

A Layer 2 circuit is a point-to-point Layer 2 connection transported by means of Multiprotocol Label Switching (MPLS) or another tunneling technology on the service provider's network. A Layer 2 circuit is similar to a circuit cross-connect (CCC) except that multiple Layer 2 circuits can be transported over a single label-switched path (LSP) tunnel between two provider edge (PE) routers. In contrast, each CCC requires a dedicated LSP.

The JUNOS implementation of Layer 2 virtual circuits supports only the remote form of a Layer 2 circuit; that is, a connection from a local customer edge (CE) router to a remote CE router. Figure 43 illustrates the components of a Layer 2 virtual circuit.

Figure 43: Components of a Layer 2 Virtual Circuit



The interfaces shown in Figure 43 are logical interfaces. Packets are sent to the remote CE router using an egress VPN label advertised by the remote PE router. The VPN label transits over an RSVP and LDP LSP (or other type) tunnel to the remote PE router connected to the remote CE router. Return traffic sent from the remote CE router to the local CE router uses an ingress VPN label advertised by the local PE router, which again transits over an RSVP and LDP LSP to the local PE router from the remote PE router. LDP is the signaling protocol used for advertising VPN labels.

Layer 2 Circuit Configuration

To configure a Layer 2 circuit, include statements at the [edit protocols l2circuit] hierarchy level:

```
[edit]
protocols {
    l2circuit {
        neighbor address {
            interface interface-name {
                virtual-circuit-id identifier;
            }
        }
        traceoptions {
            file filename <replace> <size size> <files number> <nostamp>;
            flag flag <flag-modifier> <disable>;
        }
}
```

The following sections describe how to configure Layer 2 virtual circuits:

- Configure the Neighbor and Interface on page 308
- Configure the Virtual Circuit ID on page 308
- Configure the Interface Encapsulation Type on page 309
- Configure LDP for Layer 2 Circuits on page 309
- Trace Layer 2 Circuit Creation and Changes on page 309

Configure the Neighbor and Interface

Each Layer 2 circuit is represented by the logical interface connecting the local PE router to the local CE router. All the Layer 2 circuits using a particular remote PE router designated for remote CE routers are listed under the neighbor statement (neighbor designates the PE router). Each neighbor is identified by its IP address and is usually the end-point destination for the LSP tunnel transporting the Layer 2 circuit.

Configure the Virtual Circuit ID

You configure a virtual circuit ID on each interface. Each virtual circuit ID uniquely identifies the Layer 2 circuit among all the Layer 2 circuits to a specific neighbor. The key to identifying a particular Layer 2 circuit on a PE router is the neighbor address and the virtual circuit ID. An LDP-FEC-to-label binding is associated with a Layer 2 circuit based on the virtual circuit ID in the Forwarding Equivalence Class (FEC) and the neighbor that sent this binding. It enables the dissemination of the VPN label used for sending traffic on that Layer 2 circuit to the remote CE router.

Configure the virtual circuit ID at the [edit protocols l2circuit neighbor *address* interface *interface-name*] hierarchy level:

```
[edit protocols l2circuit neighbor address interface interface-name]
virtual-circuit-id identifier;
```

Configure the Interface Encapsulation Type

Both ends of a Layer 2 circuit must connect using the same Layer 2 encapsulation. The Layer 2 encapsulation type is carried in the LDP FEC. The encapsulation type received from an FEC is matched against the local encapsulation type of the Layer 2 circuit. The Layer 2 circuit will not work if the encapsulation types do not match.

The configuration for the encapsulation type on Layer 2 virtual circuits is identical to the configuration for the CCC encapsulation type. For more information, see the *JUNOS Internet Software Configuration Guide: MPLS Applications*.

To configure the interface encapsulation for a Layer 2 circuit, include statements at the [edit interfaces] hierarchy level:

```
[edit]
interfaces {
    interface-name {
        encapsulation encapsulation-type;
        unit unit-number;
    }
}
```

Configure LDP for Layer 2 Circuits

Use LDP as the signaling protocol to advertise ingress labels to the remote PE routers. When configured, LDP examines the Layer 2 circuit configuration and initiates extended neighbor discovery for all the Layer 2 circuit neighbors (for example, remote PEs). This is similar to how LDP works when tunneled over RSVP. You must run LDP on the lo0.0 interface for extended neighbor discovery to function correctly.

For detailed information about how to configure LDP, see the *JUNOS Internet Software Configuration Guide: MPLS Applications.*

Trace Layer 2 Circuit Creation and Changes

To trace the creation of and changes to Layer 2 virtual circuits, you can specify options in the traceoptions statement at the [edit protocols l2circuit] hierarchy level:

```
[edit protocols l2circuit]
traceoptions {
    file filename <replace> <size size> <files number> <nostamp>;
    flag flag <flag-modifier> <disable>;
}
```

The following tracing flags display the operations associated with Layer 2 virtual circuits:

- connections—Layer 2 circuit connections (events and state changes)
- error—Error conditions
- FEC—Layer 2 circuit advertisements received or sent using LDP
- topology—Layer 2 circuit topology changes caused by reconfiguration or advertisements received from other PE routers

Chapter 17
Summary of Layer 2 Circuit Configuration Statements

The following sections explain the major protocol configuration statements that apply specifically to Layer 2 circuits. The statements are organized alphabetically. Protocols and the statements at the [edit protocols] hierarchy level are explained in the *JUNOS Internet Software Configuration Guide: Routing and Routing Protocols*.

interface

Syntax interface *interface-name*;

Hierarchy Level [edit protocols l2circuit neighbor *address*]

Description Interface over which Layer 2 circuit traffic travels.

Options *interface-name*—Name of the interface to configure.

Usage Guidelines See "Configure the Neighbor and Interface" on page 308.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

neighbor

Syntax neighbor *address*

Hierarchy Level [edit protocols l2ciruit]

Description Each Layer 2 circuit is represented by the logical interface connecting the local PE router to the local CE router. All the Layer 2 circuits using a particular remote PE router designated for remote CE routers are listed under the neighbor statement (neighbor designates the PE router). Each neighbor is identified by its IP address and is usually the end-point destination for the LSP tunnel (transporting the Layer 2 circuit).

Options *address*—IP address of a neighboring router.

Usage Guidelines See "Configure the Neighbor and Interface" on page 308.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

traceoptions

Syntax

```
traceoptions {
    file filename <replace> <size size> <files number> <nostamp>;
    flag flag <flag-modifier> <disable>;
    }
```

Hierarchy Level [edit protocols l2circuit]

Description Trace traffic flowing through a Layer 2 virtual circuit.

Options disable—(Optional) Disable the tracing operation. You can use this option to disable a single operation when you have defined a broad group of tracing operations, such as all.

file *filename*—Name of the file to receive the output of the tracing operation. Enclose the name within quotation marks.

files *number*—(Optional) Maximum number of trace files. When a trace file named *trace-file* reaches its maximum size, it is renamed *trace-file*.0, then *trace-file*.1, and so on, until the maximum number of trace files is reached. Then the oldest trace file is overwritten.

If you specify a maximum number of files, you also must specify a maximum file size with the size option.

Range: 2 to 1000
Default: 2 files

flag *flag*—Tracing operation to perform. To specify more than one tracing operation, include multiple flag statements.

- connections—Layer 2 circuit connections (events and state changes)
- error—Error conditions
- FEC—Layer 2 circuit advertisements received or sent by means of LDP
- topology—Layer 2 circuit topology changes caused by reconfiguration or advertisements received from other PE routers

flag-modifier—(Optional) Modifier for the tracing flag. You can specify the detail modifier if you want to provide detailed trace information.

nostamp—(Optional) Do not place timestamp information at the beginning of each line in the trace file.
Default: If you omit this option, timestamp information is placed at the beginning of each line of the tracing output.

replace—(Optional) Replace an existing trace file if there is one.
Default: If you do not include this option, tracing output is appended to an existing trace file.

size *size*—(Optional) Maximum size of each trace file, in kilobytes (KB), megabytes (MB), or gigabytes (GB). When a trace file named *trace-file* reaches this size, it is renamed *trace-file*.0. When the *trace-file* again reaches its maximum size, *trace-file*.0 is renamed *trace-file*.1 and *trace-file* is renamed *trace-file*.0. This renaming scheme continues until the maximum number of trace files is reached. Then the oldest trace file is overwritten.

If you specify a maximum file size, you also must specify a maximum number of trace files with the files option.

Syntax: *x*k to specify KB, *x*m to specify MB, or *x*g to specify GB
Range: 10 KB through the maximum file size supported on your system
Default: 1 MB

Usage Guidelines See “Trace Layer 2 Circuit Creation and Changes” on page 309.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

virtual-circuit-id

Syntax virtual-circuit-id *identifier*;

Hierarchy Level [edit protocols l2circuit neighbor *address* interface *interface-name*]

Description Uniquely identifies a Layer 2 virtual circuit.

Options None.

Usage Guidelines See “Configure the Virtual Circuit ID” on page 308.

Required Privilege Level routing—To view this statement in the configuration.
routing-control—To add this statement to the configuration.

Part 6

Appendix

Appendix A
Glossary

A

AAL
ATM adaptation layer. A series of protocols enabling various types of traffic, including voice, data, image, and video, to run over an ATM network.

active route
Route chosen from all routes in the routing table to reach a destination. Active routes are installed into the forwarding table.

add/drop multiplexer
See ADM.

Address Resolution Protocol
See ARP.

adjacency
Portion of the local routing information that pertains to the reachability of a single neighbor over a single circuit or interface.

ADM
Add/drop multiplexer. SONET functionality that allows lower-level signals to be dropped from a high-speed optical connection.

aggregation
Combination of groups of routes that have common addresses into a single entry in the routing table.

AH
Authentication Header. A component of the IPSec protocol used to verify that the contents of a packet have not been changed, and to validate the identity of the sender. *See also ESP*.

ANSI
American National Standards Institute. The United States' representative to the ISO.

APQ
Alternate Priority Queuing. Dequeuing method that has a special queue, similar to SPQ, which is visited only 50 percent of the time. The packets in the special queue still have a predictable latency, although the upper limit of the delay is higher than that with SPQ. Since the other configured queues share the remaining 50 percent of the service time, queue starvation is usually avoided. *See also SPQ*.

APS
Automatic Protection Switching. Technology used by SONET ADMs to protect against circuit faults between the ADM and a router and to protect against failing routers.

area
Routing subdomain that maintains detailed routing information about its own internal composition and that maintains routing information that allows it to reach other routing subdomains. In IS-IS, an area corresponds to a Level 1 subdomain.

In IS-IS and OSPF, a set of contiguous networks and hosts within an autonomous system that have been administratively grouped together.

area border router
Router that belongs to more than one area. Used in OSPF.

ARP Address Resolution Protocol. Protocol for mapping IP addresses to MAC addresses.

AS Autonomous system. Set of routers under a single technical administration. Each AS normally uses a single interior gateway protocol (IGP) and metrics to propagate routing information within the set of routers. Also called *routing domain*.

AS boundary router In OSPF, routers that exchange routing information with routers in other ASs.

AS external link advertisements OSPF link-state advertisement sent by AS boundary routers to describe external routes that they know. These link-state advertisements are flooded throughout the AS (except for stub areas).

AS path In BGP, the route to a destination. The path consists of the AS numbers of all routers a packet must go through to reach a destination.

ASIC Application-specific integrated circuit. Specialized processors that perform specific functions on the router.

ATM Asynchronous Transfer Mode. A high-speed multiplexing and switching method utilizing fixed-length cells of 53 octets to support multiple types of traffic.

atomic Smallest possible operation. An atomic operation is performed either entirely or not at all. For example, if machine failure prevents a transaction from completing, the system is rolled back to the start of the transaction, with no changes taking place.

Authentication Header *See AH.*

Automatic Protection Switching *See APS.*

autonomous system *See AS.*

autonomous system boundary router In OSPF, routers that exchange routing information with routers in other ASs.

autonomous system external link advertisements OSPF link-state advertisement sent by autonomous system boundary routers to describe external routes that they know. These link-state advertisements are flooded throughout the autonomous system (except for stub areas).

autonomous system path In BGP, the route to a destination. The path consists of the autonomous system numbers of all the routers a packet must pass through to reach a destination.

B

backbone area In OSPF, an area that consists of all networks in area ID 0.0.0.0, their attached routers, and all area border routers.

backplane On an M40 router, component of the Packet Forwarding Engine that distributes power, provides signal connectivity, manages shared memory on FPCs, and passes outgoing data cells to FPCs.

bandwidth The range of transmission frequencies a network can use, expressed as the difference between the highest and lowest frequencies of a transmission channel. In computer networks, greater bandwidth indicates faster data-transfer rate capacity.

Bellcore Bell Communications Research. Research and development organization created after the divestiture of the Bell System. It is supported by the regional Bell holding companies (RBHCs), which own the regional Bell operating companies (RBOCs).

BERT — Bit error rate test. A test that can be run on a T3 interface to determine whether it is operating properly.

BGP — Border Gateway Protocol. Exterior gateway protocol used to exchange routing information among routers in different autonomous systems.

bit error rate test — *See BERT*.

BITS — Building Integrated Timing Source. Dedicated timing source that synchronizes all equipment in a particular building.

Border Gateway Protocol — *See BGP*.

broadcast — Operation of sending network traffic from one network node to all other network nodes.

bundle — Collection of software that makes up a JUNOS software release.

C

CB — Control Board. Part of the host subsystem that provides control and monitoring functions for router components.

CCC — Circuit cross-connect. A JUNOS software feature that allows you to configure transparent connections between two circuits, where a circuit can be a Frame Relay DLCI, an ATM VC, a PPP interface, a Cisco HDLC interface, or an MPLS label-switched path (LSP).

CE device — Customer edge device. Router or switch in the customer's network that is connected to a service provider's provider edge (PE) router and participates in a Layer 3 VPN.

CFM — Cubic feet per minute. Measure of air flow in volume per minute.

Challenge Handshake Authentication Protocol — *See CHAP*.

channel service unit — *See CSU/DSU*.

CHAP — A protocol that authenticates remote users. CHAP is a server-driven, three-step authentication mechanism that depends on a shared secret password that resides on both the server and the client.

CIDR — Classless interdomain routing. A method of specifying Internet addresses in which you explicitly specify the bits of the address to represent the network address instead of determining this information from the first octet of the address.

CIP — Connector Interface Panel. On an M160 router, the panel that contains connectors for the Routing Engines, BITS interfaces, and alarm relay contacts.

circuit cross-connect — *See CCC*.

class of service — *See CoS*.

CLEC — (Pronounced “see-lek”) Competitive Local Exchange Carrier. Company that competes with the already established local telecommunications business by providing its own network and switching.

CLEI — Common language equipment identifier. Inventory code used to identify and track telecommunications equipment.

CLI Command-line interface. Interface provided for configuring and monitoring the routing protocol software.

client peer In a BGP route reflection, a member of a cluster that is not the route reflector. *See also nonclient peer*.

CLNP Connectionless Network Protocol. ISO-developed protocol for OSI connectionless network service. CLNP is the OSI equivalent of IP.

cluster In BGP, a set of routers that have been grouped together. A cluster consists of one system that acts as a route reflector, along with any number of client peers. The client peers receive their route information only from the route reflector system. Routers in a cluster do not need to be fully meshed.

community In BGP, a group of destinations that share a common property. Community information is included as one of the path attributes in BGP update messages.

confederation In BGP, a group of systems that appears to external autonomous systems to be a single autonomous system.

constrained path In traffic engineering, a path determined using RSVP signaling and constrained using CSPF. The ERO carried in the packets contains the constrained path information.

core The central backbone of the network.

CoS Class of service. The method of classifying traffic on a packet-by-packet basis using information in the ToS byte to provide different service levels to different traffic.

CPE Customer premises equipment. Telephone or other service provider equipment located at a customer site.

craft interface Mechanisms used by a Communication Workers of America craftsperson to operate, administer, and maintain equipment or provision data communications. On a Juniper Networks router, the craft interface allows you to view status and troubleshooting information and perform system control functions.

CSCP Class Selector Codepoint.

CSNP Complete sequence number PDU. Packet that contains a complete list of all the LSPs in the IS-IS database.

CSPF Constrained Shortest Path First. An MPLS algorithm that has been modified to take into account specific restrictions when calculating the shortest path across the network.

CSU/DSU Channel service unit/data service unit. Channel service unit connects a digital phone line to a multiplexer or other digital signal device. Data service unit connects a DTE to a digital phone line.

customer edge device *See CE device*.

D

daemon Background process that performs operations on behalf of the system software and hardware. Daemons normally start when the system software is booted, and they run as long as the software is running. In the JUNOS software, daemons are also referred to as processes.

damping Method of reducing the number of update messages sent between BGP peers, thereby reducing the load on these peers without adversely affecting the route convergence time for stable routes.

data circuit-terminating equipment *See DCE*.

data-link connection identifier *See DLCI*.

data service unit *See CSU/DSU*.

Data Terminal Equipment *See DTE*.

dcd The JUNOS software interface process (daemon).

DCE Data circuit-terminating equipment. RS-232-C device, typically used for a modem or printer, or a network access and packet switching node.

default address Router address that is used as the source address on unnumbered interfaces.

denial of service *See DoS*.

dense wavelength-division multiplexing *See DWDM*.

designated router In OSPF, a router selected by other routers that is responsible for sending link-state advertisements that describe the network, which reduces the amount of network traffic and the size of the routers' topological databases.

destination prefix length Number of bits of the network address used for host portion of a CIDR IP address.

DHCP Dynamic Host Configuration Protocol. Allocates IP addresses dynamically so that they can be reused when they are no longer needed.

Diffie-Hellman A public key scheme, invented by Whitfield Diffie and Martin Hellman, used for sharing a secret key without communicating secret information, thus precluding the need for a secure channel. Once correspondents have computed the secret shared key, they can use it to encrypt communications.

Diffserv Differentiated Service (based on RFC 2474). Diffserv uses the ToS byte to identify different packet flows on a packet-by-packet basis. Diffserv adds a Class Selector Codepoint (CSCP) and a Differentiated Services Codepoint (DSCP).

Dijkstra algorithm *See SPF*.

DIMM Dual inline memory module. 168-pin memory module that supports 64-bit data transfer.

direct routes *See interface routes*.

DLCI
Data-link connection identifier. Identifier for a Frame Relay virtual connection (also called a logical interface).

DoS
Denial of service. System security breach in which network services become unavailable to users.

DRAM
Dynamic random-access memory. Storage source on the router that can be accessed quickly by a process.

drop profile
Drop probabilities for different levels of buffer fullness that are used by RED to determine from which queue to drop packets.

DSCP
Differentiated Services Codepoint.

DSU
Data service unit. A device used to connect a DTE to a digital phone line. Converts digital data from a router to voltages and encoding required by the phone line. *See also CSU/DSU*.

DTE
Data Terminal Equipment. RS-232-C interface that a computer uses to exchange information with a serial device.

DVMRP
Distance Vector Multicast Routing Protocol. Distributed multicast routing protocol that dynamically generates IP multicast delivery trees using a technique called reverse path multicasting (RPM) to forward multicast traffic to downstream interfaces.

DWDM
Dense wavelength-division multiplexing. Technology that enables data from different sources to be carried together on an optical fiber, with each signal carried on its own separate wavelength.

Dynamic Host Configuration Protocol
See DHCP.

E

EBGP
External BGP. BGP configuration in which sessions are established between routers in different ASs.

ECSA
Exchange Carriers Standards Association. A standards organization created after the divestiture of the Bell System to represent the interests of interexchange carriers.

edge router
In MPLS, a router located at the beginning or end of a label-switching tunnel. When at the beginning of a tunnel, an edge router applies labels to new packets entering the tunnel. When at the end of a tunnel, the edge router removes labels from packets exiting the tunnel. *See also MPLS*.

EGP
Exterior gateway protocol, such as BGP.

egress router
In MPLS, last router in a label-switched path (LSP). *See also ingress router*.

EIA
Electronic Industries Association. A United States trade group that represents manufacturers of electronics devices and sets standards and specifications.

EMI
Electromagnetic interference. Any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics or electrical equipment.

encapsulating security payload
See ESP.

end system
In IS-IS, network entity that sends and receives packets.

ERO Explicit Route Object. Extension to RSVP that allows an RSVP PATH message to traverse an explicit sequence of routers that is independent of conventional shortest-path IP routing.

ESP Encapsulating security payload. A fundamental component of IPSec-compliant VPNs, ESP specifies an IP packet's encryption, data integrity checks, and sender authentication, which are added as a header to the IP packet. *See also AH*.

explicit path *See signaled path*.

Explicit Route Object *See ERO*.

export To place routes from the routing table into a routing protocol.

external BGP *See EBGP*.

external metric A cost included in a route when OSPF exports route information from external autonomous systems. There are two types of external metrics: Type 1 and Type 2. Type 1 external metrics are equivalent to the link-state metric; that is, the cost of the route, used in the internal autonomous system. Type 2 external metrics are greater than the cost of any path internal to the autonomous system.

F

fast reroute Mechanism for automatically rerouting traffic on an LSP if a node or link in an LSP fails, thus reducing the loss of packets traveling over the LSP.

FEAC Far-end alarm and control. T3 signal used to send alarm or status information from the far-end terminal back to the near-end terminal and to initiate T3 loopbacks at the far-end terminal from the near-end terminal.

FEB Forwarding Engine Board. In M5 and M10 routers, provides route lookup, filtering, and switching to the destination port.

firewall A security gateway positioned between two different networks, usually between a trusted network and the Internet. A firewall ensures that all traffic that crosses it conforms to the organization's security policy. Firewalls track and control communications, deciding whether to pass, reject, discard, encrypt, or log them. Firewalls also can be used to secure sensitive portions of a local network.

FIFO First in, first out.

flap damping *See damping*.

flapping *See route flapping*.

Flexible PIC Concentrator *See FPC*.

Forwarding Engine Board *See FEB*.

forwarding information base *See forwarding table*.

forwarding table JUNOS software forwarding information base (FIB). The JUNOS routing protocol process installs active routes from its routing tables into the Routing Engine forwarding table. The kernel copies this forwarding table into the Packet Forwarding Engine, which is responsible for determining which interface transmits the packets.

FPC Flexible PIC Concentrator. An interface concentrator on which PICs are mounted. An FPC inserts into a slot in a Juniper Networks router. *See also PIC.*

FRU Field-replaceable unit. Router component that customers can replace onsite.

G

group A collection of related BGP peers.

H

hash A one-way function that takes a message of any length and produces a fixed-length digest. In security, a message digest is used to validate that the contents of a message have not been altered in transit. The Secure Hash Algorithm (SHA-1) and Message Digest 5 (MD5) are commonly used hashes.

Hashed Message Authentication Code *See HMAC.*

HDLC High-level data link control. An International Telecommunication Union (ITU) standard for a bit-oriented data link layer protocol on which most other bit-oriented protocols are based.

HMAC Hashed Message Authentication Code. A mechanism for message authentication that uses cryptographic hash functions. HMAC can be used with any iterative cryptographic hash function—for example, MD5 or SHA-1—in combination with a secret shared key. The cryptographic strength of HMAC depends on the properties of the underlying hash function.

hold time Maximum number of seconds allowed to elapse between the time a BGP system receives successive keepalive or update messages from a peer.

host module On an M160 router, provides routing and system management functions of the router. Consists of the Routing Engine and Miscellaneous Control Subsystem (MCS).

host subsystem Provides routing and system-management functions of the router. Consists of a Routing Engine and an adjacent Control Board (CB).

I

IANA Internet Assigned Numbers Authority. Regulatory group that maintains all assigned and registered Internet numbers, such as IP and multicast addresses. *See also NIC.*

IBGP Internal BGP. BGP configuration in which sessions are established between routers in the same ASs.

ICMP Internet Control Message Protocol. Used in router discovery, ICMP allows router advertisements that enable a host to discover addresses of operating routers on the subnet.

IDE Integrated Drive Electronics. Type of hard disk on the Routing Engine.

IEC International Electrotechnical Commission. *See ISO.*

IEEE Institute of Electronic and Electrical Engineers. International professional society for electrical engineers.

IETF Internet Engineering Task Force. International community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet.

IGMP Internet Group Membership Protocol. Used with multicast protocols to determine whether group members are present.

IGP Interior gateway protocol, such as IS-IS, OSPF, and RIP.

IKE Internet Key Exchange. The key management protocol used in IPSec, IKE combines the ISAKMP and Oakley protocols to create encryption keys and security associations.

import To install routes from the routing protocols into a routing table.

ingress router In MPLS, first router in a label-switched path (LSP). *See also egress router*.

inter-AS routing Routing of packets among different ASs. *See also EBGP*.

intercluster reflection In a BGP route reflection, the redistribution of routing information by a route reflector system to all nonclient peers (BGP peers not in the cluster). *See also route reflection*.

interface routes Routes that are in the routing table because an interface has been configured with an IP address. Also called *direct routes*.

intermediate system In IS-IS, network entity that sends and receives packets and that can also route packets.

internal BGP *See IBGP*.

Internet Key Exchange *See IKE*.

Internet Protocol Security *See IPSec*.

Internet Security Association and Key Management Protocol *See ISAKMP*.

intra-AS routing The routing of packets within a single AS. *See also IBGP.*

IP Internet Protocol. The protocol used for sending data from one point to another on the Internet.

IPSec Internet Protocol Security. The industry standard for establishing VPNs, IPSec comprises a group of protocols and algorithms that provide authentication and encryption of data across IP-based networks.

ISAKMP Internet Security Association and Key Management Protocol. A protocol that allows the receiver of a message to obtain a public key and use digital certificates to authenticate the sender's identity. ISAKMP is designed to be key exchange independent; that is, it supports many different key exchanges. *See also IKE and Oakley*.

IS-IS Intermediate System-to-Intermediate System protocol. Link-state, interior gateway routing protocol for IP networks that also uses the shortest-path first (SPF) algorithm to determine routes.

ISO International Organization for Standardization. Worldwide federation of standards bodies that promotes international standardization and publishes international agreements as International Standards.

ISP Internet service provider. Company that provides access to the Internet and related services.

ITU International Telecommunications Union (formerly known as the CCITT). Group supported by the United Nations that makes recommendations and coordinates the development of telecommunications standards for the entire world.

J

jitter Small random variation introduced into the value of a timer to prevent multiple timer expirations from becoming synchronized.

K

kernel forwarding table *See forwarding table*.

L

label In MPLS, 20-bit unsigned integer in the range 0 through 1048575, used to identify a packet traveling along an LSP.

label-switched path (LSP) Sequence of routers that cooperatively perform MPLS operations for a packet stream. The first router in an LSP is called the *ingress router*, and the last router in the path is called the *egress router*. An LSP is a point-to-point, half-duplex connection from the ingress router to the egress router. (The ingress and egress routers cannot be the same router.)

label switching *See MPLS*.

label-switching router *See LSR*.

link Communication path between two neighbors. A link is *up* when communication is possible between the two end points.

link-state PDU (LSP) Packets that contain information about the state of adjacencies to neighboring systems.

local preference Optional BGP path attribute carried in internal BGP update packets that indicates the degree of preference for an external route.

loose In the context of traffic engineering, a path that can use any route or any number of other intermediate (transit) points to reach the next address in the path. (Definition from RFC 791, modified to fit LSPs.)

LSP *See label-switched path (LSP)) or link-state PDU (LSP).*

LSR Label-switching router. A router on which MPLS and RSVP are enabled and is thus capable of processing label-switched packets.

M

martian address Network address about which all information is ignored.

mask *See subnet mask*.

MBGP Multiprotocol BGP. An extension to BGP that allows you to connect multicast topologies within and between BGP ASs.

MBone Internet multicast backbone. An interconnected set of subnetworks and routers that support the delivery of IP multicast traffic. The MBone is a virtual network that is layered on top of sections of the physical Internet.

MCS Miscellaneous Control Subsystem. On an M160 router, provides control and monitoring functions for router components and SONET clocking for the router.

MD5 Message Digest 5. A one-way hashing algorithm that produces a 128-bit hash. It is used in AH and ESP. *See also SHA-1*.

MDRR Modified Deficit Round Robin. A method for selecting queues to be serviced.

MED Multiple exit discriminator. Optional BGP path attribute consisting of a metric value that is used to determine the exit point to a destination when all other factors in determining the exit point are equal.

mesh Network topology in which devices are organized in a manageable, segmented manner with many, often redundant, interconnections between network nodes.

Message Digest 5 *See MD5*.

MIB Management Information Base. Definition of an object that can be managed by SNMP.

midplane Forms the rear of the PIC cage on M5 and M10 routers and the FPC card cage on M20 and M160 routers. Provides data transfer, power distribution, and signal connectivity.

Miscellaneous Control Subsystem *See MCS*.

MPLS Multiprotocol Label Switching. Mechanism for engineering network traffic patterns that functions by assigning to network packets short labels that describe how to forward them through the network. Also called *label switching*. *See also traffic engineering*.

MTBF Mean time between failure. Measure of hardware component reliability.

MTU Maximum transfer unit. Limit on segment size for a network.

multicast Operation of sending network traffic from one network node to multiple network nodes.

multicast distribution tree The data path between the sender (host) and the multicast group member (receiver or listener).

multiprotocol BGP *See MBGP*.

Multiprotocol Label Switching *See MPLS*.

N

neighbor Adjacent system reachable by traversing a single subnetwork. An immediately adjacent router. Also called a *peer*.

NET Network entity title. Network address defined by the ISO network architecture and used in CLNS-based networks.

network layer reachability information *See NLRI*.

network link advertisement An OSPF link-state advertisement flooded throughout a single area by designated routers to describe all routers attached to the network.

Network Time Protocol *See NTP*.

NIC Network Information Center. Internet authority responsible for assigning Internet-related numbers, such as IP addresses and autonomous system numbers. *See also IANA*.

NLRI Network layer reachability information. Information that is carried in BGP packets and is used by MBGP.

nonclient peer In a BGP route reflection, a BGP peer that is not a member of a cluster. *See also client peer*.

not-so-stubby area *See NSSA*.

NSAP Network service access point. Connection to a network that is identified by a network address.

n-selector Last byte of an nonclient peer address.

NSSA Not-so-stubby area. In OSPF, a type of stub area in which external routes can be flooded.

NTP Network Time Protocol. Protocol used to synchronize computer clock times on a network.

O

Oakley A key determination protocol based on the Diffie-Hellman algorithm that provides added security, including authentication. Oakley was the key-exchange algorithm mandated for use with the initial version of ISAKMP, although various algorithms can be used. Oakley describes a series of key exchanges called “modes” and details the services provided by each; for example, Perfect Forward Secrecy for keys, identity protection, and authentication. *See also ISAKMP*.

OC Optical Carrier. In SONET, Optical Carrier levels indicate the transmission rate of digital signals on optical fiber.

OSI Open System Interconnection. Standard reference model for how messages are transmitted between two points on a network.

OSPF Open Shortest Path First. A link-state IGP that makes routing decisions based on the shortest-path-first (SPF) algorithm (also referred to as the *Dijkstra algorithm*).

P

package A collection of files that make up a JUNOS software component.

Packet Forwarding Engine The architectural portion of the router that processes packets by forwarding them between input and output interfaces.

path attribute Information about a BGP route, such as the route origin, AS path, and next-hop router.

PCI Peripheral Component Interconnect. Standard, high-speed bus for connecting computer peripherals. Used on the Routing Engine.

PCMCIA Personal Computer Memory Card International Association. Industry group that promotes standards for credit card-size memory or I/O devices.

PDU Protocol data unit. IS-IS packets.

PE router Provider edge router. A router in the service provider's network that is connected to a customer edge (CE) device and that participates in a Virtual Private Network (VPN).

PEC
Policing Equivalence Classes. In traffic policing, a set of packets that is treated the same by the packet classifier.

peer
An immediately adjacent router with which a protocol relationship has been established. Also called a *neighbor*.

Perfect Forward Secrecy
See PFS.

PFE
See Packet Forwarding Engine.

PFS
A condition derived from an encryption system that changes encryption keys often and ensures that no two sets of keys have any relation to each other. The advantage of PFS is that if one set of keys is compromised, only communications using those keys are at risk. An example of a system that uses PFS is Diffie-Hellman.

Physical Interface Card
See PIC.

PIC
Physical Interface Card. A network interface–specific card that can be installed on an FPC in the router.

PIM
Protocol Independent Multicast. A protocol-independent multicast routing protocol. PIM Sparse Mode routes to multicast groups that might span wide-area and interdomain internets. PIM Dense Mode is a flood-and-prune protocol.

PLP
Packet Loss Priority.

PLP bit
Packet Loss Priority bit. Used to identify packets that have experienced congestion or are from a transmission that exceeded a service provider's customer service license agreement. This bit can be used as part of a router's congestion control mechanism and can be set by the interface or by a filter.

policing
Applying rate limits on bandwidth and burst size for traffic on a particular interface.

pop
Removal of the last label, by a router, from a packet as it exits an MPLS domain.

PPP
Point-to-Point Protocol. Link-layer protocol that provides multiprotocol encapsulation. It is used for link-layer and network-layer configuration.

precedence bits
The first three bits in the ToS byte. On a Juniper Networks router, these bits are used to sort or classify individual packets as they arrive at an interface. The classification determines the queue to which the packet is directed upon transmission.

preference
Desirability of a route to become the active route. A route with a lower preference value is more likely to become the active route. The preference is an arbitrary value in the range 0 through 255 that the routing protocol process uses to rank routes received from different protocols, interfaces, or remote systems.

preferred address
On an interface, the default local address used for packets sourced by the local router to destinations on the subnet.

primary address
On an interface, the address used by default as the local address for broadcast and multicast packets sourced locally and sent out the interface.

primary interface
Router interface that packets go out when no interface name is specified and when the destination address does not imply a particular outgoing interface.

Protocol-Independent Multicast *See PIM*.

provider edge router *See PE router*.

provider router Router in the service provider’s network that does not attach to a customer edge (CE) device.

PSNP Partial sequence number PDU. Packet that contains only a partial list of the LSPs in the IS-IS link-state database.

push Addition of a label or stack of labels, by a router, to a packet as it enters an MPLS domain.

Q

QoS Quality of service. Performance, such as transmission rates and error rates, of a communications channel or system.

quality of service *See QoS*.

R

RADIUS Remote Authentication Dial-In User Service. Authentication method for validating users who attempt to access the router using Telnet.

Random Early Detection *See RED*.

rate limiting *See policing*.

RBOC (Pronounced “are-bock”) Regional Bell operating company. Regional telephone companies formed as a result of the divestiture of the Bell System.

RDRAM RAMBUS dynamic random access memory.

RED Random Early Detection. Gradual drop profile for a given class that is used for congestion avoidance. RED tries to anticipate incipient congestion and reacts by dropping a small percentage of packets from the head of the queue to ensure that a queue never actually becomes congested.

Rendezvous Point *See RP*.

Resource Reservation Protocol *See RSVP*.

RFC Request for Comments. Internet standard specifications published by the Internet Engineering Task Force.

RFI Radio frequency interference. Interference from high-frequency electromagnetic waves emanating from electronic devices.

RIP Routing Information Protocol. Distance-vector interior gateway protocol that makes routing decisions based on hop count.

route flapping Situation in which BGP systems send an excessive number of update messages to advertise network reachability information.

route identifier IP address of the router from which a BGP, IGP, or OSPF packet originated.

route reflection
In BGP, configuring a group of routers into a cluster and having one system act as a route reflector, redistributing routes from outside the cluster to all routers in the cluster. Routers in a cluster do not need to be fully meshed.

router link advertisement
OSPF link-state advertisement flooded throughout a single area by all routers to describe the state and cost of the router's links to the area.

routing domain
See AS.

Routing Engine
Architectural portion of the router that handles all routing protocol processes, as well as other software processes that control the router's interfaces, some of the chassis components, system management, and user access to the router.

routing instance
A collection of routing tables, interfaces, and routing protocol parameters. The set of interfaces belongs to the routing tables and the routing protocol parameters control the information in the routing tables.

routing table
Common database of routes learned from one or more routing protocols. All routes are maintained by the JUNOS routing protocol process.

RP
For PIM-SM, a core router acting as the root of the distribution tree in a shared tree.

rpd
JUNOS software routing protocol process (daemon). User-level background process responsible for starting, managing, and stopping the routing protocols on a Juniper Networks router.

RPM
Reverse path multicasting. Routing algorithm used by DVMRP to forward multicast traffic.

RSVP
Resource Reservation Protocol. Resource reservation setup protocol designed to interact with integrated services on the Internet.

S

SA
Security association. An IPSec term that describes an agreement between two parties about what rules to use for authentication and encryption algorithms, key exchange mechanisms, and secure communications.

SAP
Session Announcement Protocol. Used with multicast protocols to handle session conference announcements.

SAR
Segmentation and reassembly. Buffering used with ATM.

SCB
System Control Board. On an M40 router, the part of the Packet Forwarding Engine that performs route lookups, monitors system components, and controls FPC resets.

SCG
SONET Clock Generator. Provides Stratum 3 clock signal for the SONET/SDH interfaces on the router. Also provides external clock inputs.

SDH
Synchronous Digital Hierarchy. CCITT variation of SONET standard.

SDP
Session Description Protocol. Used with multicast protocols to handle session conference announcements.

SDRAM
Synchronous dynamic random access memory.

Secure Hash Algorithm
See SHA-1.

secure shell
See SSH.

security association *See SA.*

Security Parameter Index *See SPI.*

SFM Switching and Forwarding Module. On an M160 router, a component of the Packet Forwarding Engine that provides route lookup, filtering, and switching to FPCs.

SHA-1 Secure Hash Algorithm. A widely used hash function for use with Digital Signal Standard (DSS). SHA-1 is more secure than MD5.

shortest-path-first algorithm *See SPF.*

signaled path In traffic engineering, an explicit path; that is, a path determined using RSVP signaling. The ERO carried in the packets contains the explicit path information.

SIB Switch Interface Board. Provides the switching function to the destination Packet Forwarding Engine.

simplex interface An interface that assumes that packets it receives from itself are the result of a software loopback process. The interface does not consider these packets when determining whether the interface is functional.

SNMP Simple Network Management Protocol. Protocol governing network management and the monitoring of network devices and their functions.

SONET Synchronous Optical Network. High-speed (up to 2.5 Gbps) synchronous network specification developed by Bellcore and designed to run on optical fiber. STS-1 is the basic building block of SONET. Approved as an international standard in 1988. *See also SDH.*

SPF Shortest-path first, an algorithm used by IS-IS and OSPF to make routing decisions based on the state of network links. Also called the *Dijkstra algorithm*.

SPI Security Parameter Index. A portion of the IPSec Authentication Header that communicates which security protocols, such as authentication and encryption, are used for each packet in a VPN connection.

SPQ Strict Priority Queuing. Dequeuing method that provides a special queue that is serviced until it is empty. The traffic sent to this queue tends to maintain a lower latency and more consistent latency numbers than traffic sent to other queues. *See also APQ.*

SSB System and Switch Board. On an M20 router, Packet Forwarding Engine component that performs route lookups and component monitoring and monitors FPC operation.

SSH Secure shell. Software that provides a secured method of logging in to a remote network system.

SSRAM Synchronous Static Random Access Memory.

static LSP *See static path.*

static path In the context of traffic engineering, a static route that requires hop-by-hop manual configuration. No signaling is used to create or maintain the path. Also called a *static LSP.*

STM Synchronous Transport Module. CCITT specification for SONET at 155.52 Mbps.

strict
In the context of traffic engineering, a route that must go directly to the next address in the path. (Definition from RFC 791, modified to fit LSPs.)

STS
Synchronous Transport Signal. Synchronous Transport Signal level 1. Basic building block signal of SONET, operating at 51.84 Mbps. Faster SONET rates are defined as STS-*n*, where *n* is a multiple of 51.84 Mbps. *See also SONET*.

stub area
In OSPF, an area through which, or into which, AS external advertisements are not flooded.

subnet mask
Number of bits of the network address used for host portion of a Class A, Class B, or Class C IP address.

summary link advertisement
OSPF link-statement advertisement flooded throughout the advertisement's associated areas by area border routers to describe the routes that they know about in other areas.

sysid
System identifier. Portion of the ISO nonclient peer. The sysid can be any 6 bytes that are unique throughout a domain.

System and Switch Board
See SSB.

T

TACACS +
Terminal Access Controller Access Control System Plus. Authentication method for validating users who attempt to access the router using Telnet.

TCP
Transmission Control Protocol. Works in conjunction with Internet Protocol (IP) to send data over the Internet. Divides a message into packets and tracks the packets from point of origin to destination.

ToS
Type of service. The method of handling traffic using information extracted from the fields in the ToS byte to differentiate packet flows.

traffic engineering
Process of selecting the paths chosen by data traffic in order to balance the traffic load on the various links, routers, and switches in the network. (Definition from http://www.ietf.org/internet-drafts/draft-ietf-mpls-framework-04.txt.) *See also MPLS*.

transit area
In OSPF, an area used to pass traffic from one adjacent area to the backbone or to another area if the backbone is more than two hops away from an area.

transit router
In MPLS, any intermediate router in the LSP between the ingress router and the egress router.

transport mode
An IPSec mode of operation in which the data payload is encrypted, but the original IP header is left untouched. The IP addresses of the source or destination can be modified if the packet is intercepted. Because of its construction, transport mode can be used only when the communication end point and cryptographic end point are the same. VPN gateways that provide encryption and decryption services for protected hosts cannot use transport mode for protected VPN communications. *See also tunnel mode*.

Triple-DES
A 168-bit encryption algorithm that encrypts data blocks with three different keys in succession, thus achieving a higher level of encryption. Triple-DES is one of the strongest encryption algorithms available for use in VPNs.

tunnel
Private, secure path through an otherwise public network.

tunnel mode An IPSec mode of operation in which the entire IP packet, including the header, is encrypted and authenticated and a new VPN header is added, protecting the entire original packet. This mode can be used by both VPN clients and VPN gateways, and protects communications that come from or go to non-IPSec systems. *See also transport mode*.

Tunnel PIC A physical interface card that allows the router to perform the encapsulation and decapsulation of IP datagrams. The Tunnel PIC supports IP-IP, GRE, and PIM register encapsulation and decapsulation. When the Tunnel PIC is installed, the router can be a PIM rendezvous point (RP) or a PIM first-hop router for a source that is directly connected to the router.

type of service *See ToS*.

U

unicast Operation of sending network traffic from one network node to another individual network node.

UPS Uninterruptible power supply. Device that sits between a power supply and a router (or other piece of equipment) the prevents undesired power-source events, such as outages and surges, from affecting or damaging the device.

V

vapor corrosion inhibitor *See VCI*.

VCI Vapor corrosion inhibitor. Small cylinder packed with the router that prevents corrosion of the chassis and components during shipment.

VCI Virtual circuit identifier. 16-bit field in the header of an ATM cell that indicates the particular virtual circuit the cell takes through a virtual path. Also called a *logical interface. See also VPI*.

virtual circuit identifier *See VCI*.

virtual link In OSPF, a link created between two routers that are part of the backbone but are not physically contiguous.

virtual path identifier *See VPI*.

virtual private network *See VPN*.

Virtual Router Redundancy Protocol *See VRRP*.

VPI virtual path identifier. 8-bit field in the header of an ATM cell that indicates the virtual path the cell takes. *See also VCI*.

VPN virtual private network. A private data network that makes use of a public TCP/IP network, typically the Internet, while maintaining privacy with a tunneling protocol, encryption, and security procedures.

VRRP Virtual Router Redundancy Protocol. On Fast Ethernet and Gigabit Ethernet interfaces, allows you to configure virtual default routers.

W

wavelength-division multiplexing *See WDM*.

WDM Wavelength-division multiplexing. Technique for transmitting a mix of voice, data, and video over various wavelengths (colors) of light.

WFQ Weighted Fair Queuing.

weighted round-robin *See WRR*.

WRR Weighted round-robin. Scheme used to decide the queue from which the next packet should be transmitted.

Part 7

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